Paradigm Architectural Education for the IR 4.0 Era

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Abstract: Through the last century, three different technical advances namely steam-powered mechanical manufacturing, electricity-powered mass production, and electronics created what is known as the industrial revolutions. Through the last decade, many new technological advances created what is started to be known as the fourth industrial revolution or IR4. This revolution affected all the industry sectors. Education organizations who are responsible for educating and preparing the young workers to join the workforce should adopt these new systems and technologies in the education process. This paper investigates the opportunities and challenges facing both the construction industry and teaching systems. Moreover, it put some highlights on the available technologies and how they can impact the construction industry and the required skills for the new Jobs that is going to be needed. Finally, the paper concludes with a framework to be adopted by the architectural teaching organizations to be able to benefit from the ongoing transformation in the construction and design industry.

Keywords: IR 4.0, Construction industry, Architectural education.

1. INTRODUCTION

Technologies affected daily life style and affected the way we work, entertain and live. Social media platforms and video streaming services have transformed entertainment industry. Emerging of electronic shopping giants like Amazon and Alibaba have changed the retailing concepts. These innovated technologies do not only satisfy the growing demands for better and more effective life style. As these technologies improved the life style, they flipped the work force structure and changed created whole new zones required skills to flourish. (Temidayo. O. Osunsanmi, 2018)

Table (1): Technological advancements that constitutes the four industrial revolutions: (WILFRIED A. ARVIND CJ, 2016).

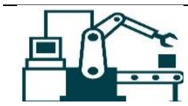
	Industry 1.0	Steam power, Water power, Mechanization, and transportation.
	Industry 2.0	Electricity, Mass production, Assembly lines.
	Industry 3.0	Electronics, Computer, Automation and Communication.
	Industry 4.0	Cyber physical systems, Internet of things and Networks.

Table (1) presents the main technological advances that made these four industrial revolutions. Construction industry started lately to benefit from these modern technologies in achieving fast, accurate and sustainable operations. These coming changes in the construction industry will reshape the skills and competencies needed to thrive. However, construction industry sustained its traditions relying on manual labour, mechanical technology and well-established operational models. Climate change, resource depletion, and rapid urbanization are the factors thrusting the industry trends toward utilizing more innovative technological solutions. Obligated by the newly adopted laws reduce pollution and maintain sustainable development, construction industries started to gradually started to utilize new technologies like prefabrication, 3D printing, automatization and robotics. Adopting these new technologies is expected to have big economic, social and educational impact, since construction sector constitutes 6% of global GDP.

1.1. What is IR 4.0

The term IR 4.0 emerged in 2011 as the implementation of the innovative digital technologies in industry. Despite the excessive use of the IR 4.0 term in many international economic organizations, there is no known formal definition for it. However, Michael Buehler defined it as "the integration of complex physical machinery and devices with networked sensors and software, used to predict, control and plan for better business and societal outcomes." The term was built on ten technical advances namely, artificial intelligence, robotics, internet of things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, quantum computing. (Wesam S. Alaloul, 2018) Moreover, it is described by a fusion of innovation through which mixing physical components with digital environment is possible (N. Kudriashov et al., 2016).

2. CONSTRUCTION 4.0

Construction industry accounts for 6% of global GDP and employs more than 100 million people worldwide. Fig. 1 illustrates the percentage of employment in the construction industry through the last decade. Full-scale modernization of construction industry would save up to 16%. (Michael Buehler, 2018).

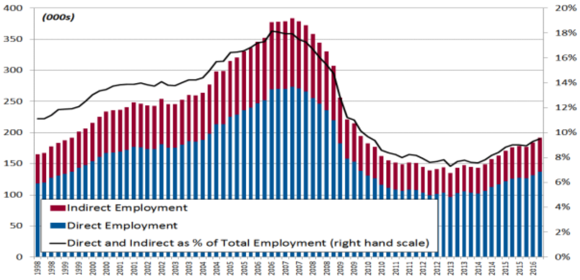


Fig.1. Total direct and indirect employment in construction 1998 - 2016

As shown in fig. 2 adopting the following technical advances can contribute positively to the construction industry expected shift: (Michael Buehler, 2018)

- Prefabrication & modular construction
- Nanotechnology, biotechnology & advanced materials
- 3-D printing & additive manufacturing
- Robotics & autonomous machines
- Virtual & Augmented Reality
- Big data & Cloud real time collaboration
- Internet of Things & Artificial intelligence
- Energy storage
- 3D scanning & photogrammetry
- Building Information Modeling

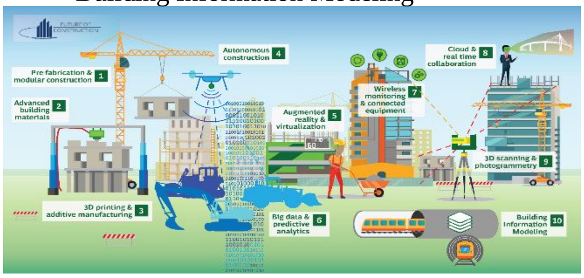


Fig.2. Top 10 disruptive technologies in infrastructure and construction; (Clearbox, 2107)

2.1. Directives of Construction 4.0

The global construction industry ended 2018 with growth rate up to 3%, based mostly on private projects. Estimation reports shows that, full-scale digitization could generate increase of 12-20% in annual expenses. Global trends should motivate construction companies to rethink traditional industry practices and start to consider innovative solutions and new technologies. As per united nations habitat reports on global urbanization, over 200,000 persons moving to urban areas within cities every day. To meet this global growing demand on housing units, construction industries have to utilize the available technologies build cheaper, faster, cleaner. (DKM economic, 2016)

As always, construction industry should anticipate the changes and diversification. The expected countless changes in the construction industry make it very hard predict the future scenarios. However, through engaging stakeholders a variety of possible futures scenarios can be prepared.

The World Economic Forum (WEF) along with 30 companies developed three different scenarios for the industry based on global trends. These scenarios show that existing capabilities, business models and strategies will not be good enough to support the achieving the objectives. Several common good actions should be taken by companies to remain relevant were identified. Industry must act now to avoid future dramatic changes and uncertain future for the global industry and its 100 million employees. WEF argues that industry should adopt the following technologies:

- Automation and digitalization of production processes, leading to ‘smart manufacturing’.
- The advent of the Internet of Things and cloud computing, as well as the
- Massive processing of Big Data information,

To facilitate analysis of the production life cycle in real time and create knowledge-based decisions aligned with the learning curves of the ERPs. While Anna Davis concluded in her research that the following are the main six drivers of industry change:

1. Extreme longevity: Increasing global lifespans change the nature of careers and learning
2. Rise of smart machines and systems: Workplace automation nudges human workers out of rote, repetitive tasks.
3. Computational world: Massive increases in sensors and processing power make the world a programmable system
4. New media ecology: New communication tools require new media literacies beyond text
5. Super structed Organizations Social technologies drive new forms of production and value creation
6. Globally connected world: Increased global interconnectivity puts diversity and adaptability at the center of organizational operations. (Anna Davies, 2011)

2.2. Required activities to modernize construction industry

The following actions are truly relevant, whatever unfolds:

- Start to build the required skills and attract new talents: A quite different skills and talents are required for adopting the new technologies. Industry should direct and lead the efforts to upgrade the today’s workforce.
- Create a global platform for collaboration between industry’s value chain members: Fragmentation and disintegration of the value chain will hold back any development. Data flow

and integrated systems are basic ingredient for IR 4.0 implementation.
- Consider scale when adopting suitable advanced technologies: Aiming for more productivity, construction industry must adopt the suitable technologies and rely on talented skills that can utilize digital technologies.
- Utilize Building Information Models throughout the different construction phases: Upgrade existing infrastructure asset to embrace new models of business and management.

2.3. Benefits of adopting construction 4.0:

Embracing these innovative tools in the construction process will help in enhancing the whole process in terms of time loss, data inconsistency, and isolated process. It will change not only design, construction and maintain buildings, but also will change how buildings will:

- Utilize smart materials and innovative technologies to make buildings more intelligent.
- Exploit autonomous machinery through different phases of production, to maintain accurate and faster jobs.
- Use technology to enhance design and construction output.
- Make relevant information available to develop rapid informed resolution.
- Improving efficiency and resource use through using collaborative design, construction and operations through utilizing Cloud technology and big data concepts.
- Invest in infra-structure for digital operation solutions

This will result in automated accurate coordinated designs, faster operations, reduced cost, more sustainable design and construction tools, real time flow of information between site and office.

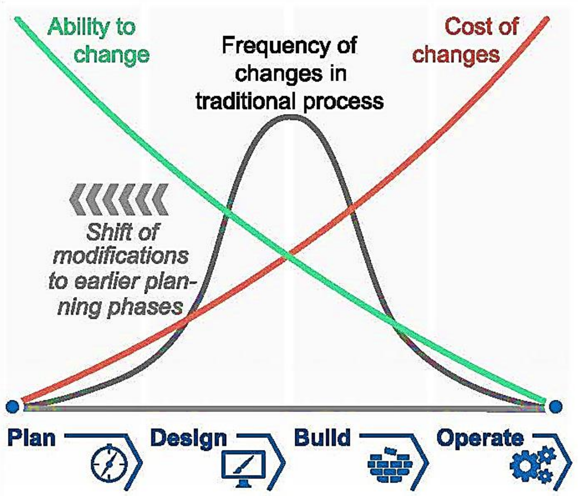


Fig.3. Cost of change in construction life cycle of buildings (WEF, 2016)

2.4. Challenges

It is difficult to anticipate the whole scheme of challenges but some of them can be predicted for example:

- **Size and change cost**: Different sectors and enterprises are shifting to construction 4.0 with different speeds based on their size and business plans. Large companies and smaller enterprises are in the same value chain. This dictate that larger companies should help smaller ones to develop the whole industry. Instead small firms, new form of SMEs should cooperate and integrate in innovative way
- **Codes and standards**: New standards are needed very soon, but it is difficult to know to define the areas of change. For instance, standards and codes for data handling, data ownership and cyber protection is required to maintain efficiency safety and sustainability within the digital work environment.
- **Design qualities and uniqueness**: Maintaining aesthetics and quality of design within the digital design processes.
- **Skilled and talented workforce**: As per the US National Association of Homebuilders, construction industry has a major concern they have a shortage in skilled construction workers. Their studies show that recruiting and managing talents has become even more challenging. A World Economic Forum report on global employment trends shows that in addition to instability in the workforce demand and composition due to the existing shortage in skilled labour, driven by the growing demand, there will be a higher demand on new skill sets at all levels, driven by surging technology.
- **Technology implementation challenges**: There is many issues regarding the adopted technologies. The following is examples of these issues:

  a) Existing robots are not smart enough to adopt to different site conditions and to interact with each other to prevent collisions.

  b) The collective communal memories had a bad image of hastily and poor quality repetitive prefabricated buildings. Overcoming this mental barrier would be achieved through allowing more personalization.

  c) Adopting 3d printing in construction does not produce a finished surface. It still requires manual work in terms of installation of utilities. Moreover, it requires an expensive and very large machinery. (Mcgreal, 2017) (Michael Buehler, 2018)

3. EDUCATION 4.0

In a survey covered industry CEOs attending at the 2018 World Economic Forum in Davos, 74% of the investigated population put, attracting new talents and improving the skills of the existing workforce as the industry first priority. Improving integration and collaboration along the value chain came in the second category with 65% while adopting advanced technologies came as the third key action to be considered with 61%. The chart in figure 3 illustrates responses of the CEOs regarding to their expectations for the industry practices in the very near future. (Michael Max, 2108) (Till Zupancic, 2018).

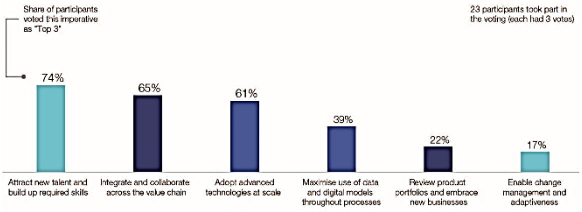


Fig.4. CEOs and ministers' priorities to transform the industry (Michael Max, 2108)

The impact of adopting construction 4.0 on jobs are difficult to predict. The change is potentially extremely fast, but the lack of skills could create an obstacle to achieving growth and productivity gains in the short term.

- Design in Cloud environment.
- Virtual detailed designs.
- Automated accurate coordinated designs.
- Faster Operations.
- Reduced cost.
- More sustainable design tools.
- Real time flow of information between site and office.

Ward predicted that productivity is expected to increase; many existing tasks will disappear, and many manual jobs will be automated eventually. That said, there could be an improvement in working environment satisfaction. (Ward, 2011). Figure 5 demonstrates the main four fields of technological application that will require new skills to join the workforce.

Fig.5. Four main technological fields that require new skilled workers

Most of the current architectural education practices are carried out by traditional methods, ignoring contemporary developments, and thus, default information is transferred to the students. However, according to today's modern developments, the learning process should allow the student and the teacher to work together to generate new information (Hare K. & Serbülent V., 2018). In anticipation of the arrival of a new creative economy current academic institutions around the world are changing. At the moment there is much interest, debate and research in the study of creativity, creative learning and teaching, the nature of creative genius, creative play, imagination and invention, and in educational policy making. The development of the techniques, tools and methods for teaching and assessment of creativity must be developed and tailored to suit the many disciplines of study that arise from a multiplicity of academic cultures (Ken S., 2014).

Several transformations are being witnessed as a reaction to a number of paradigm shifts. Three knowledge content areas are emerging to reflect continuous shifts in knowledge content. These are: environment-behavior studies (EBS), sustainability and environmental consciousness, and digital technologies or virtual practices (Salama A., 2007). Environment-behavior studies (EBS) is a knowledge component integral to creating better environments. Many critics called for the reconsideration of the social and behavioral aspects of architecture. Environment-behavior paradigm can be defined as the systematic examination of relationships between human behavior, cultural values, and the physical environment (Salama A., 2008). Another form of knowledge content transformation is sustainability and environmental consciousness. In the last two decades, the concept of sustainability has emerged in response to several environmental problems. Ecological consciousness was raised as a reaction to the overall overwhelming global environmental degradation. Many conferences, symposia, and colloquia have addressed environmental issues on the policymaking levels. Eco-development, ecosystem planning, bioregional planning, and green and sustainable design are all new ideologies and concepts that place emphasis on resolving environmental problems caused by human activities. They address the kind of development that meets the needs of the present generation, without compromising the ability of future generations to meet their own needs (Salama A., 2008). Digital technology or virtual practice is the third form of knowledge content transformations. Recent years have witnessed advances in the development of telecommunication technologies. Digital technologies and design in virtual environments are re-shaping architectural education and practice. Developments in CAD, visualization, and digital modelling coupled with the advanced technology to communicate data, images, and life action design experiences, have enabled virtual dimensions in studio instruction (Salama A., 2008). Fig. 6 represents the conclusion of these main transformations and their impact on architectural education.

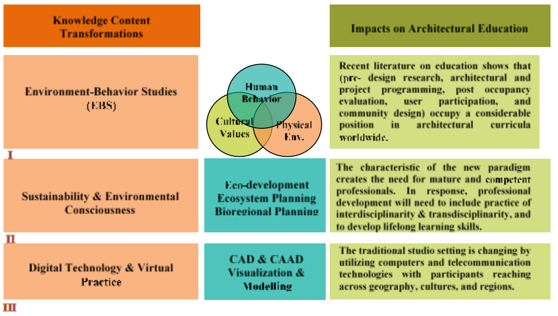


Fig.6. Knowledge transformations and their impact on architectural education

3.1. Required specialties and skills

Skills are needed to bridge the gap between engineering and computer science, machine learning, and artificial intelligence. In the design field, main four fields will require skills in many sub-specialties.

Required Skills include: Robotic and automation designers, intelligent system engineers, and ecosystems of automation technologies, (DKM economic, 2016) (Hartmann, 2013):

1. Modelling & simulation will require skills in the field of energy modelling and CFD while
2. ACMTV & IAQ will open the chance for skilled workers in chiller plants design, Indoor Air Quality and ACMV technologies.
3. Smart building systems will require skills in the field of users' behavior and wireless sensor systems. In addition to this, skills will be required in passive design systems and smart materials.
4. Zero energy buildings dictate that skills in the fields of livability and human comfort.

Required skills for Construction 4:

Sense-making: ability to determine the deeper meaning or significance of what is being expressed.

Social intelligence: ability to connect to others in a deep and direct way, to sense and stimulate reactions and desired interactions.

Novel & adaptive thinking: proficiency at thinking and coming up with solutions and responses beyond that which is rote or rule-based.

Cross-cultural competency: ability to operate in different cultural settings.

Computational thinking: ability to translate vast amounts of data into abstract concepts and to understand data-based reasoning

New-media literacy: ability to critically assess and develop content that uses new media forms, and to leverage these media for persuasive communication

Transdisciplinarity: literacy in and ability to understand concepts across multiple disciplines

Design mindset: ability to represent and develop tasks and work processes for desired outcomes

Cognitive load management: ability to discriminate and filter information for importance, and to understand how to maximize cognitive functioning using a variety of tools and techniques

Virtual collaboration: ability to work productively, drive engagement, and demonstrate presence as a member of a virtual team (Anna Davies, 2011) (Hartmann, 2013) (Ward, 2011)

3.2. Educational Organizations' Role

Educational institutions at the primary, secondary, and post-secondary levels, are largely the products of technology infrastructure and social circumstances of the past. The landscape has changed and educational institutions should consider how to adapt quickly in response. This research proposes an integrated approach consists of a tri-based development structure that is might be divided into, Fig. 7:

- Transdisciplinary Including experiential learning that gives prominence to soft skills—such as the ability to collaborate, work in groups, read social cues, and respond adaptively and Integrating interdisciplinary training that allows students to develop skills and knowledge in a range of subjects. The transdisciplinary paradigm may be defined as a focus on insisting on a values orientation for interactivity design as a higher order concern than particular collections of methods or domains of expertise. Design frameworks, values and ethics, design for important themes such as sustainability, equity, adaptation, justice, social responsibility, and so forth. Students learn how to bring a values orientation to interaction design and explanation of interaction design.
- Knowledge Interactivity Placing additional emphasis on developing skills such as critical thinking, insight, and analysis capabilities
- Technology Integration the Integrates new-media literacy into education programs, establish and upgrade labs and facilitates state of the art technologies for students. Virtual reality technology which is one of the layers of these experiences changes and influences our time, dimension and architecture perceptions by taking us into a different universe than physical space that is experienced spiritually and mentally in new space creations. There is a different depiction of the reality in this universe and provides a new universe experience by being nourished by technology in sensorial wise. The position of virtual reality in architectural education becomes more apparent. 3D perception of students would be enhanced by implementation VR in architectural pedagogy and also conceptual and spatial experiments with architecture and design. Designing VR environments needed

interdisciplinary expertise and also the contribution of architectural thinking to increase its spatial experience. How the VR reconfigure architectural design and production is an interesting research area for the architecture schools. They are experimenting spaces that explore new horizons for architecture. The implementation of VR in architectural pedagogy is structured in different ways in different concepts. In the selected 3 cases the VR technology is used in different types of teaching/experimenting with different concepts and duration, the course/ project/ experiment descriptions are taken from the websites of the universities or related publications (Elif S. M., 2019).

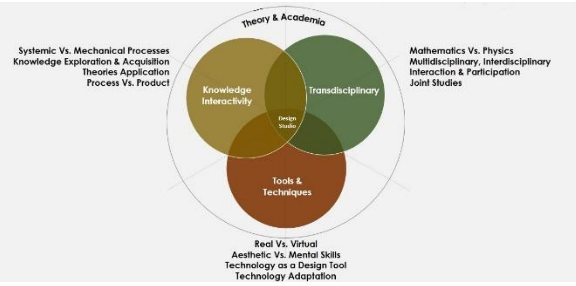


Fig.7. The tri-based model for enhancing architectural education

CONCLUSIONS

The researchers can conclude some actions to be considered by the industry attract more talents that include but not limited to:

- Prioritize talent management
- Rejuvenate corporate culture
- Invest in diversity
- Leverage technology and innovation
- Foster continuous learning and career development
- Create relevant incentives
- Redefine the public image of construction
- Collaborate systematically

The research suggests some recommendations on different levels:

- Highlight the benefits of Industry 4.0, for decision makers and education planners.
- Make major efforts to train and educate students and young talents.
- Make technologies available and affordable so that they can be used in labs
- Ensure digital inclusion
- Move from competition to connection and collaboration between educational institution and industry firms
- Take a customized approach to prepare for Industry 4.0
- Adbot problem based learning strategy.
- Exploit the potential of Industry 4.0 to address climate change and conserve the environment
- Create awareness of the importance of innovation in general, and digital innovation in particular
- Educate in innovation management.
- Identify organizations' improvement potentials in innovation management and in digital innovation.
- Take action to gain in agility by improved innovation management capabilities to embrace Industry 4.0.

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