Industry 4.0 Awareness on Built Environment Professionals: A Study on the Current State of Knowledge and Adoption in UAE

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Abstract

The Fourth Industrial Revolution, also known as Industry 4.0, has brought a significant change in the way industries operate worldwide. This technological revolution has transformed traditional manufacturing processes and has ushered in a new era of automation, artificial intelligence, big data, and the Internet of Things (IoT). These innovations have enabled a higher level of connectivity and efficiency across industries, including the built environment sector. This study aims to assess the level of Industry 4.0 awareness and adoption among Built Environment Professionals (BEPs). BEPs are a group of professionals who are responsible for the planning, design, construction, and maintenance of the built environment, including architects, engineers, builders, and facility managers. This research will employ a mixed-method approach, including a survey and interviews, to gather data on BEPs' current understanding of Industry 4.0 technologies and how they are integrating them into their work processes. The findings of this study will help to identify the gaps in the current knowledge and skills of BEPs with regards to Industry 4.0 technologies. The research will also explore the challenges faced by BEPs in adopting Industry 4.0 technologies and the potential benefits that can be gained from their integration. The results of this study can be used to inform the development of training programs and professional development opportunities for BEPs to enhance their knowledge and skills in Industry 4.0 technologies, thereby improving the efficiency and effectiveness of the built environment sector.

Thus, to pursue the aim of this study, the data and views were collected from more than 200 professionals and the Interviews were conducted with the senior professionals for further analysis. At the end of the study, the findings revealed that there is serious concern of awareness on important technologies like CPS, BIM, AI, and Virtual reality, which are going to play an important role in the Built Environment Industry soon. Moreover, it was observed that, both the survey participants, Interviewees and their respective Organizations were having less usage on the important technologies like Building Information Modelling, Cyber Physical systems at their organization.

Keywords: Industry 4.0, Cyber-Physical System (CPS), Information and Communication Technology (ICT), Physical-Digital-Physical Loop (PDP), Built Environment Professionals (BEPs)

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1.0. Introduction:

The term "Industry 4.0" was first coined by Germany in 2011 as a part of the strategy to improve the high-tech Industries in Germany through the adoption of ICT. According to the Author Jennifer, the Fourth Industrial Revolution is an umbrella term which encompasses all the mega trends happening due to the Cyber-Physical System (CPS) and ICT(Castañeda-Navarrete et al., 2020). When the CPS and ICT application is used in the construction process, it becomes Construction 4.0; subsequently, when it is used in the Manufacturing Industry, it becomes Industry 4.0.Therefore the primary foundation of the Industry 4.0 is ICT and CPS(Gürdür *et al.*, 2016). The cyber link between the digital world and the physical world will be seamlessly done both ways in a Physical-Digital-Physical loop(Cotteleer, 2017). The Cyber-Physical link refers to the network connections between humans, machines, products, and objects through ICT systems.

CPS can create a replica of the building in the physical world, called the "Digital twin", through technologies like "Building Information Modelling". The Digital Twin of the building can serve as a medium to observe, visualize, analyze, and control the physical structure or twin in the real world (Shelden, 2018). As the digital model is already available, these technologies can also be adapted to support the Facilities Management function. For example, RFID can incorporate barcodes, which can be used with Augmented Reality and BIM to locate the equipment and facilitate Maintenance quickly. Therefore, the Digital technologies such as BIM and Augmented Virtual reality is expected to play a significant role in transferring existing building asset from the physical world to the digital world. In contrast, physical technologies like 3D printing, Industrialized construction will do the same in moving the digital model to the physical world in the case of new building design and execution. The physical and digital worlds will be linked through the Internet of Things, Actuators, sensors, and Networks. Therefore, Fourth Industrial Revolution will expect future BEPs to perform in a globally networked environment between the physical and virtual worlds. Hence, in the built environment sector, Industry 4.0 has the potential to revolutionize the way buildings are designed, constructed, and managed, improving productivity, efficiency, and sustainability. However, the successful implementation of Industry 4.0 technologies in the built environment sector requires professionals who possess the necessary skills and knowledge. Even though, there were significant number of studies on the awareness of Industry 4.0 and usage on other professions, there are only limited study available on the BEP professionals. Thus, understanding the level of awareness and adoption of Industry 4.0 among built environment professionals is crucial to meet the industry's evolving needs.

This research aims to investigate the current state of Industry 4.0 awareness and adoption among built environment professionals in the United Arab Emirates (UAE) and to identify the skills and knowledge required to facilitate the transition towards Industry 4.0. The findings of this study will be of significant value to professionals, policymakers, and academic institutions involved in the built environment sector, and contribute to the sector's overall readiness to embrace Industry 4.0.

2.0 Literature Review

2.1 UAE Built Environment: Adapting to Rapid Digital and Green Changes

UAE has implemented key policies and strategies to ensure the nation remains at the forefront of modern technologies and trends. Change is the Inherent part of any crisis, whereas rapid change is the reality of the Covid-19 crisis, especially for the building and construction Industry. The Covid Crisis has accelerated this change, and digital technology has become the new normal in any Industry, including building construction and operation(Ulrik Branner and Thomas Goubau, 2020).

Post the Covid-19 crisis, UAE Leadership realized that the economic models with traditional policies in boosting only the economy, job growth and financial returns alone in a narrow-minded manner are not sufficient. To identify the future trends, the Centennial Lab at the UAE Prime Minister's office, along with the United Nations and Horizon Group, published "Future Possibilities Report 2020" on the 75th Anniversary of the United Nations. The report identified six transformational trends that would have a likely impact of 5 to 10 years on the country.

The Below drawing figure the six transformational trends and their impact on the Built Environment.

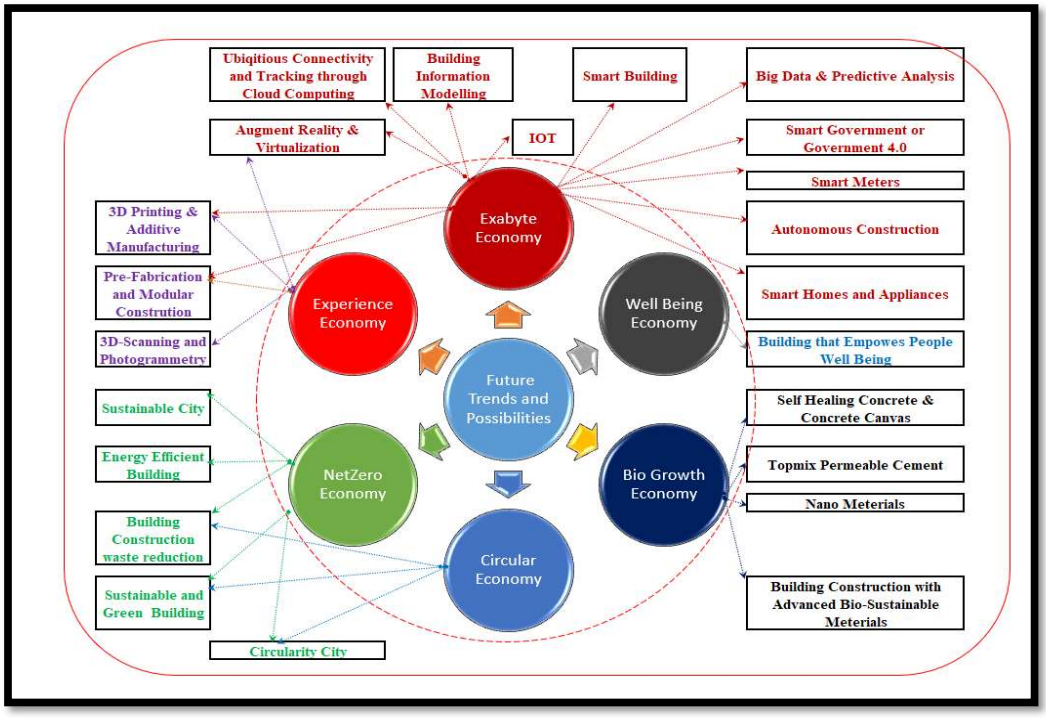

Figure 1. Six Transformational Trends Identified by "Future Possibilities Report" (Authors' Representation)

These transformational trends are expected to have a massive change in the Built Environment. A digital ecosystem is a group of products, people or enterprises working in an interdependent manner on a common digitized standard platform for their typical gain or mutual interest (Panetta, 2016). Therefore, in a virtually focused future economy of UAE, the entire life cycle of the building construction and operation will be autonomous in the digital ecosystem. The Construction process is expected to change from a highly fragmented project-based approach based on unique customer requirements to a product-based system with standardization and flexibility. The construction and Facility Management of the building will be autonomous with less human intervention, and the human workforce will be required in the future only for robot maintenance and project supervision. The project will be supervised and collaborated more digitally only to oversee the project and to maintain the robots. Digitalization and technological advancement will push the industry players to shift towards off-site construction, Prefabrication, and Additive Manufacturing. The factories will mass produce and supply large quantities of Customized modules in less than a decade. There will be a new business model created out of a large amount of data that exist in the virtual world. The Digitized building objects and the sensors' data will allow companies to generate new revenues and services. The Business model of stand-alone contractors, sub-contractors without highly specialized skills and Operation & Maintenance companies will be at risk of disruption, as their work is now automated. Those companies that cannot embrace digital or leverage digital technologies will soon be out of business in the UAE.

The Built Environment accounts for 70% of Energy consumption in this region compared to the global average of 40%(Tabet Afoul et al., 2018). The per capita electricity consumption in UAE is also considered one of the highest in the world. This pushes the UAE Government to work towards Green economic models such as Net Zero Economy, Circular Economy, Well Being Economy, and Bio-Growth Economy. UAE Ministry of Climate Change, in partnership with "The Global Green Growth Institute", has developed a road map ", National Climate Change plan of UAE 2017-2050", to strengthen the national action plans for mitigating climate change(Government, 2017). The UAE Strategy exemplified by the UN Sustainability targets will compel the Built Environment Industry players to factor sustainability in their value chains, such as building materials, construction process and design. The industry players will adopt Innovative technologies and new sustainable materials to reduce the environmental impact. Design and Engineering Firms will move from traditional design practices to "Nature Positive Built Environment Design", where the entire ecosystem will be placed at the Centre of the design rather than placing humans as the only focus of the design(Akanksha Khatri and Dominic Waughray, 2020). The Built Environment sector will see the increased deployment of resource engineers, circular Economy specialists and simulation experts to produce the asset with the most negligible environmental impact over their Entire Building Life Cycle.

The building materials will be taxed based on their origin and recyclability. The industry will prefer locally sourced or renewable bio-engineered materials to make the building more durable and sustainable. Most of the buildings will be 3D printed out of new materials, as

this will minimize construction waste. UAE plans to have 25% of Dubai's buildings printed by 3D printing technology by 2030(Rajan et al., 2018).

Industry players with extensive knowledge of Sustainable practices and the latest technology only can survive and thrive in the green future, as sustainability will become a prime criterion for making a choice.

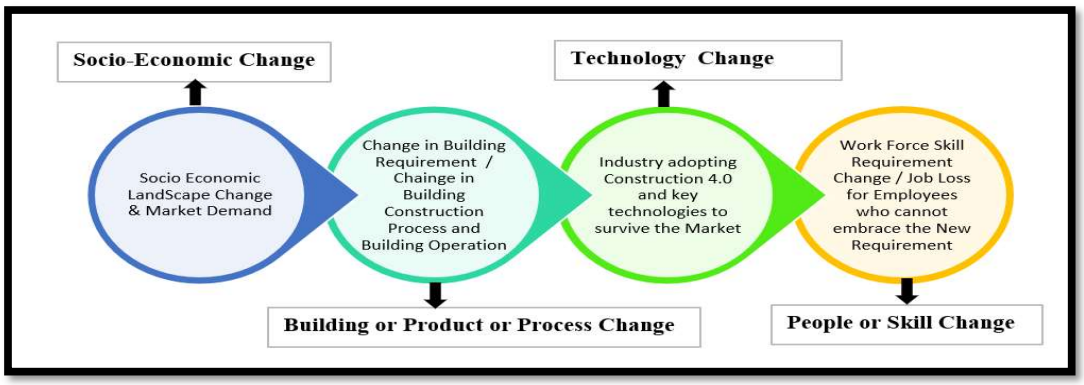

Figure 2. Work Force Skill Change due to Economy & Industry (Source: Authors' Representation)

Based on the above discussion, the buildings are changing from "grey and dumb" to "Green and smart". Those players who cannot think smart and green cannot create superior value for the end-users. The industry players who cannot adapt will completely disappear from the market in a few years. According to the Mckinsey report, construction is identified as one of the top six sectors, where 60% of the Jobs have the potential to be automated in the Middle East(Aus dem Moore, Chandran and Schubert, 2018). Many occupations related to the Built Environment are threatened by technology, Data, and computerization(Thompson and Waller, 2017). As the socio-economy of the UAE changes to a Digital, Industrial, and sustainable economy, the industry and its workforce have no other option to change, as depicted below.

Based on the discussion, it was clear that the Building Industry is fast changing due to the Innovative strategies and policies of the UAE government. The UAE government's innovative strategies and policies have led to a fast-changing Building Industry. To keep up with the industry's changes, Built Environment professionals such as Architects, Engineers, and technicians need to be aware of digital, physical, and sustainable technologies. They must also develop leadership skills and a mindset for lifelong learning, growth, and resilience to remain relevant in the industry. Failure to do so may lead to the displacement of human workers by disruptive intelligent machines.

3.0 Methodology:

To critically examine the industry 4.0 technology awareness and its usage, the survey and the Interview was conducted through an with BEPs. The primary target of the survey participants was the professionals actively involved in Building Construction and

Operations. The main goal of that survey was to collect feedback from the professionals on the awareness and the usage of Industry 4.0 Technologies. The survey was distributed to the professionals through social media, linked in and through what's app. The total number of responses received was 203. After the survey, the Interview was conducted with the Consultants and senior professionals shown below (Table-1) to understand better and analyze the survey data collected.

The heterogeneousness of the survey data is reinforced by the fact the survey response was from different hierarchy level with staff (45%, 92 replies), Managers (26%, 53 responses), Senior Managers (10%, 20 responses), Directors/ Corporate executives (8%, 16 responses) and Others (10.89%, 22 responses). The response came from a broad level of Industry professionals working across the Industries of Real Estate Development (Pre-construction), Construction and Operations. The Survey response came from a comprehensive group of Industry professionals working across the Industries of Real Estate Development (Pre-construction), Construction and Operations.

Sr.No	Role	Experience (Years)	Industry type	Expertise	Interview Date and Time
1	Managing Director (Interviewee-1)	16	Developer/ Mall Management	Mall Management / Real Estate Developer	16th June 2021, 6 till 7 PM (1 Hour)
2	Consultant (Interviewee-2)	16	Critical Facilities Management / Data Centre / Consultancy	Critical Facilities / Data Center / Consultancy / ICT Resilience Expert	18th June 2021,8 till 9 AM (1 Hour)
3	Senior Manager (Interviewee-3)	15	IOT / Industry 4.0 / Digital Transformation	Artificial Intelligence of Things / Cloud / Mobility / Industry 4.0 / Digital Transformation / Connected Living	19th June 2021, 12.30 till 1.30 PM (1 Hour)
4	Senior Manager (Interviewee-4)	15	Digital Transformation / IOT Solutions	IIOT / Automation / End-End Digital Transformation	02nd July 2021, 5 till 05.40 PM (40 minutes)
5	Senior Manager (Interviewee-5)	20	Construction / Property and Asset Management	Solution Architect - M-Serivces / ERP / IOT	03rd July 2021, 5 till 5.30 PM (30 minutes)

Table 1-Interview Details (Qualitative Analysis)

The Interviewee participants (Table 1) were carefully handpicked with more than 15 years of domain experience in Building Construction and Maintenance, Digital Transformation, and Industry 4.0 Technologies. The survey participants comprised only 10% having less than a year of experience, 27% having more than 15 years and 28% having 9 to 15 years. Hence, most survey participants had enough experience to provide legitimate survey responses on this industry.

4.0 Survey & Interview Data Results and Discussion

Participants in the survey were presented with a list of Industry 4.0 technologies and asked to rate their opinions on two aspects using a scale of 1 to 5:

1. Participant Awareness on the listed Industry 4.0 technologies
2. Extend of Usage in their Organization (Listed Technology Usage)

The list of Industry 4.0 technologies was obtained from the "Industry 4.0 Opportunities, behind the Challenge" report by the United Nations Industrial Development Organization(Dr. Mirjana Stankovic *et al.*, 2017).The survey response was analyzed and grouped under three categories of "Low, High and Average" Awareness. As shown in the survey response table below (Table-2), the top three technologies having awareness among professionals are Mobile Technologies, RFID, and the Internet of things. The professionals do not understand Cyber-Physical Systems, Augmented reality, 3D Printing and Building Information Modelling in the respective Order. There is the slightest awareness of Cyber-physical Systems, with only 25% of the respondent choosing the "High awareness" option.

	LOW	AVERAGE	HIGH	
Technology Awarness	1 & 2	3	4 & 5	TOTAL
Mobile and Wearable Technologies	13%	21%	65%	100%
RFID and Barcoding Technology	19%	28%	53%	100%
Internet of things (IOT) , Sensors and Actuator Technology	20%	25%	55%	100%
Artificial Intelligence and Machine Learning	25%	28%	48%	100%
Robotics and Automation	25%	29%	46%	100%
Big Data, Predictive Analytics and Cloud Computing	26%	26%	48%	100%
Industrialized Construction	29%	35%	36%	100%
Drones and Un-Manned Aerial Vehicle System	33%	28%	39%	100%
Building Information Modelling (BIM)	29%	37%	33%	100%
3D Printing and Additive Manufacturing	35%	31%	34%	100%
Augmented and Virtual Reality Technologies	34%	31%	35%	100%
Cyber Physical System(CPS)	45%	30%	25%	100%

Table 2- Table showing the Survey Response on Industry 4.0 Technologies Awareness

The below table (Table-3) shows the "Extend of Usage" response summarized in three categories "High, Average and Low". A comparison between the current usage (derived from survey responses) with the "Expected usage" derived from the literature review of "The Construction 4.0: Roadmap to the Shaping the Future(El Jazzar *et al.*)" is made and shown below.

	LOW	AVERAGE	HIGH		Expected Usage			
Extend of Usage in your Organization (Current Usage)	1 & 2	3	4 & 5	TOTAL	Planning	Design	Construction	Facility Management
Mobile and Wearable Technologies	23%	20%	58%	100%	LOW	LOW	MEDIUM	VERY HIGH
RFID and Barcoding Technology	28%	24%	47%	100%	LOW	LOW	MEDIUM	VERY HIGH
Internet of things (IOT) , Sensors and Actuator Technology	31%	27%	42%	100%	LOW	LOW	MEDIUM	VERY HIGH
Artificial Intelligence and Machine Learning	36%	27%	37%	100%	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH
Robotics and Automation	39%	28%	33%	100%	LOW	MEDIUM	HIGH	HIGH
Big Data, Predictive Analytics and Cloud Computing	46%	21%	34%	100%	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH
Industrialized Construction	46%	24%	30%	100%	MEDIUM	MEDIUM	VERY HIGH	LOW
Drones and Un-Manned Aerial Vehicle System	50%	22%	28%	100%	LOW	MEDIUM	HIGH	HIGH
Building Information Modelling (BIM)	49%	27%	24%	100%	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH
3D Printing and Additive Manufacturing	49%	28%	23%	100%	HIGH	HIGH	VERY HIGH	LOW
Augmented and Virtual Reality Technologies	59%	16%	25%	100%	HIGH	HIGH	MEDIUM	MEDIUM
Cyber Physical System(CPS)	54%	26%	20%	100%	LOW	LOW	VERY HIGH	VERY HIGH

Planning | Design | Construction | Facility Management

Table 3 -Table Showing the Survey Response on "Low, Average and High" Usage

Based on both the tables (Table-2 and 3), the First three technologies are same for the "Awareness and extend of usage", which indicates that there is already a heavy penetration of these three technologies (Mobile, RFID and IoT) in the Built Environment Industry Construction and Operation. 3D Printing and Additive Manufacturing come last, with only 11 (only 8%) respondents stating that their organization has high usage. Even though Dubai has an ambitious strategy of having at least 25% of its buildings 3D Printed by 2030 (Dubai 3D Printing 2030), the market penetration of 3D Printed technology, according to the table below, is less. This indicates that there will be a supply-side issue when there is a requirement for 3D-printed buildings in this region to meet the ambitious government target.

From the above comparison table, it is observed that the cyber-physical system has got minor usage in this region. Even the Interviewee participants, who are in the technology space of the Built Environment, are not aware of CPS much; instead, they understand it in terms of digitalization. Results inferences that the industry is not well advanced towards industry 4.0, as the cyber-physical system is the core of the Fourth Industrial Revolution. Less than 50% of the organization are using BIM, Big Data and Artificial Intelligence. This is alarming, as there will be a high reliance on these technologies for the entire life cycle of the building Construction and Operation in the future. Based on the survey result, the question was posed to the Interviewees about why Mobile Technologies, RFID and IoT are in the top three spots on awareness, impact, and usage when compared to other technologies like BIM, 3D Printing and Cyber-physical systems.

The Interviewee Participant responded that it is because of the awareness, cost, and people's resistance to change. In the case of Mobile or wearable technologies or RFID or IoT, the technology is intuitive to your brain, as people can touch and feel comfortable using the applications with limited training. Moreover, mobile or wearables or RFID technologies

were a luxury in the past decades. Now, they have become a necessity due to their wide adaptation among the masses due to their cheap cost.

The cost of implementing or adapting Mobile Technology or application is easy, as the platform or hardware or wireless infrastructure to adopt it is already available. But in the case of BIM or 3D Printing or Cyber-physical systems, the awareness is less, and the technology is not widely adopted till now. Moreover, the cost of these technologies is high and requires skilled personnel or specialized training to implement this on the projects. The price is high and requires much change and training, so there is resistance to change. Therefore, the technology is adopted where there is a mandatory requirement for the project.

5.0 Theoretical and Practical Implementation:

The results of the study indicate that the built environment industry in the region is not well advanced towards industry 4.0, as less than 50% of the organizations are using BIM, Big Data, and Artificial Intelligence. This presents an opportunity for researchers and academics to further explore the potential benefits of these technologies in the industry and identify ways to increase their adoption. One theoretical implementation could involve developing a training and education program for industry professionals on the benefits of these technologies and how to effectively implement them in projects. This program could include courses on BIM, data analytics, and AI, as well as hands-on training sessions with industry-specific software and hardware. The program could be offered in partnership with industry associations or professional organizations to ensure maximum exposure and adoption. Another theoretical implementation could involve developing a framework for the integration of cyber-physical systems in the built environment. This framework could include guidelines for selecting and implementing appropriate CPS technologies, as well as a roadmap for their adoption and integration into the construction and operation of buildings. The framework could be developed in collaboration with industry experts and organizations to ensure it is practical and applicable to real-world projects.

One practical implementation could involve partnering with local governments and organizations to incentivize the adoption of these technologies in building projects. This could include offering tax breaks or other financial incentives to companies that incorporate BIM, Big Data, and AI into their projects. It could also involve providing funding or resources to support the training and education of industry professionals in these technologies. Another practical implementation could involve developing pilot projects to showcase the benefits of these technologies in real-world scenarios. These projects could be developed in collaboration with industry partners and could include the integration of BIM, data analytics, and AI in building design, construction, and operation. The results of these pilot projects could be shared with industry professionals to demonstrate the potential benefits of these technologies and encourage their wider adoption.

Overall, the study highlights the need for increased awareness and adoption of advanced technologies in the built environment industry. Furthermore, it may be beneficial to conduct more research and development to make CPS more accessible and affordable for the industry. This could involve creating open-source CPS platforms that can be easily

customized and integrated into existing building management systems. In summary, promoting awareness and education, incentivizing adoption, and investing in research and development are practical steps that can be taken to increase the adoption of CPS in the built environment industry. By doing so, the industry can take a significant step towards embracing Industry 4.0 and reaping the benefits that come with it.

6.0 Limitations and Re-commendation

One limitation of the study is that it was limited to a specific region, the UAE, and therefore may not be generalizable to other regions or countries. Additionally, the sample size of the survey was relatively small, and the study relied on self-reported data, which may be subject to response bias. Finally, the study focused primarily on the awareness and usage of specific technologies and did not explore in-depth the reasons behind the lack of adoption or awareness, nor did it examine the potential challenges or barriers to implementing these technologies in the UAE Building Industry.

Based on the findings of this study, there are several recommendations for concerned stakeholders in the UAE Building Industry. Firstly, there is a need to invest in training programs and workshops to increase awareness and knowledge of Industry 4.0 technologies, such as CPS, BIM, AI, and Virtual Reality. These programs should be accessible and affordable to professionals and companies of all sizes.

Secondly, the concerned stakeholders should collaborate with academic institutions and research centers to foster innovation and research in the field of Industry 4.0. This collaboration will lead to the development of new technologies and solutions that are tailored to the needs of the UAE Building Industry.

Thirdly, there is a need for government support in promoting the adoption of Industry 4.0 technologies through the provision of incentives and subsidies. This will encourage companies to invest in these technologies and stay competitive in the market.

Finally, concerned stakeholders should also promote knowledge-sharing platforms and forums to encourage professionals to exchange ideas and experiences on the implementation of Industry 4.0 technologies in the Built Environment. This will lead to a more informed and collaborative industry, which will be better equipped to face the challenges and opportunities of the Fourth Industrial Revolution.

7.0 Conclusion:

After the study, it was found that there is a concerning lack of awareness and usage of important technologies, such as Building Information Modelling, Cyber-Physical systems, Industrialized construction, and 3D Printing, in the UAE Building Industry. Even experts in technology in the Built Environment have limited knowledge of CPS and understand it more in terms of digitalization. This study emphasizes the urgent need for the adoption of CPS, BIM, AI, and Virtual Reality to transform the UAE Building Industry. The workforce

must embrace the digital and physical technologies discussed in this study to remain relevant in the market. Professionals and companies that are resistant to change risk becoming obsolete.

Therefore, it is crucial for current professionals and companies to take these findings seriously and adapt to the changes. Ultimately, this will lead to a more advanced and competitive Built Environment industry in the UAE.

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