Challenges and Opportunity in Digital Transformation of Construction industry: A Role of Industry 4.0.

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Abstract

The terminology of 4th industrial revolution was incepted by the government of Germany which illustrates and encompasses the rapid technological advancement in manufacturing sector and outline the coherent policy framework to compete with global digital transformation. Initially the concept was introduced for manufacturing industry but later it has been adopted by various organizations and construction industry remain no exception. In addition to the third industrial revolution, industry 4.0 incorporates the adoption of IoT (internet of things), cyber security, augmented reality, big data, autonomous robot, additive manufacturing, simulations, system integration and cloud computing. The construction industry is considered as the third largest industrial sector and still adoption of industry 4.0 is awaited. There are numerous factors which obstruct the adoption of the fourth revolution. This study set the objective to identify the opportunity and challenges that lie within the adoption of industry 4.0 in the construction sector. Industry professionals are approached and their opinions and understandings of the IR4.0

are evaluated. The implementation of fourth industrial revolution will not only reduce the cost of construction processes but the efficiency and productivity will also be enhanced.

Key words: Construction industry, Industrial revolution, IR4.0, Digital Construction

Introduction: The First Three Industrial Revolutions

The last few decades have seen the world being evolved and achieved far beyond than what it has achieved previously. The transition of population from predominantly rural setting to developed urban settings (increase in urban population of 200,000 people per day globally) has affected the construction industry on a mass scale [1]. The demand for affordable housing was inevitable and has risen to levels, the world had not seen before [2], associated with a simultaneous requirement of social, utilities and transportation infrastructures.

These ongoing emerging challenges have provided the construction industry an opportunity to review and renovate itself. These adopted changes have not only affected the price of living but also contribute on the environmental effects in growing urban centres. The construction industry has been able in ensuring a reduction in the cost of housing and implementing environmentally friendly tactics through efficient usage of uncommon resources and constructing eco-friendly buildings[3]. These achievements influence the economy positively with an assurance that the global infrastructure gap is constricted and the overall economy has been able to boost and flourish.

Since the beginning of the industrialization back in 1700s, industrial revolution has played a very important and vital role. The mechanical innovation and introduction of water and steam driven mechanical equipment has not only changed the economic scene but was able to enhance and contribute in the industrial sector as well. Another wave of industrial revolution occurred in 1870s, when the power sector was revolutionized by the introduction of electric energy which also affected the industrial sector in a unique way. Due to the introduction of electric energy driven machines, the industries were able to achieve the dream of mass production which they have been struggling and thriving to achieve [4]. The third industrial revolution was the rising up of the electronics industry in the 1970s. The transformation of analogue electronics and mechanical devices to the present digital technological world is the result of the significant Digital Insurrection.

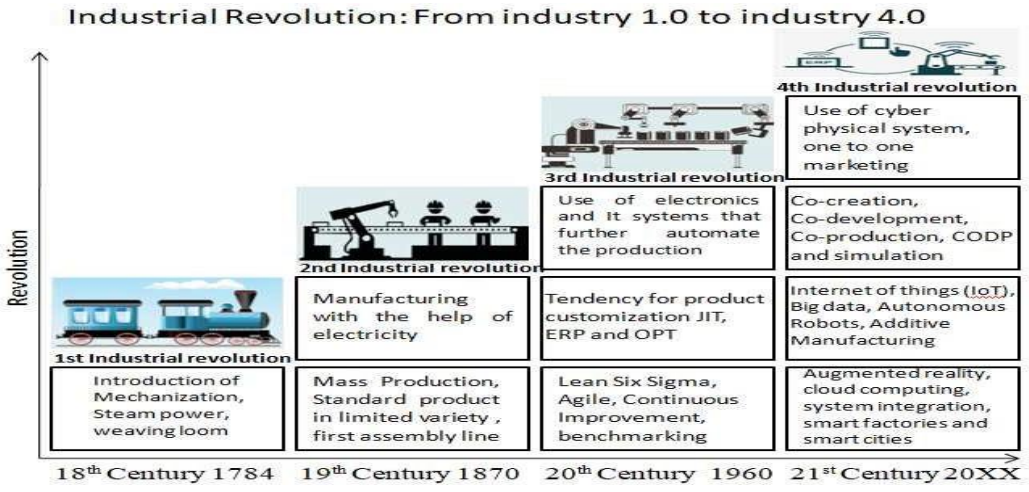


Figure 1: Industrial revolution from industry 1.0 to industry 4.0

Industrial Revolution 4.0:

The Fourth Industrial Revolution (IR4.0) is based on and linked to the digital insurrection which connects the technology and the societies together. This phenomenal development has demonstrated itself in many ways and has successfully been able to distort the ranks between the physical, digital and biological bodies[5] IR4.0 is not limited to the incorporation of new technology but it also supports sustainability [6]with energy and energy efficiency going hand in hand as major contributing factors [7]. Implementation of innovations for energy efficiency is very hard [8] and renewable energy consumption still floats around 19.2%[8].

The IR4.0 stresses upon the viability and sustainability of the whole manufacturing process and have an advanced mechanism of the convolution to integrate the production as well as the product practices [9] becoming part of a sustainable system [10]]. Industrial revolution 4.0 has been recognized as a term for the development of the industrial sector in Germany, which was meant to embrace automation and data exchange[5] .

Similar to manufacturing sector, construction sector can also be an important beneficiary of the IR4.0. The implementation of IR4.0 will ensure that the production efficiency will be achieved through the utilization of the advanced technologies like mechanized automation to operate with no human intervention. The benefits are quite obvious, as this implementation not only improves the quality of the product but at the same time reduces distribution time which will further enhance the operation performance. [11] has identified numerous benefits of adopting fourth revolution in construction industry. They categorized implementation mechanism into three clusters; Smart Factories, Simulation and Modeling, and Digitalization and Virtualization as shown in figure 2.

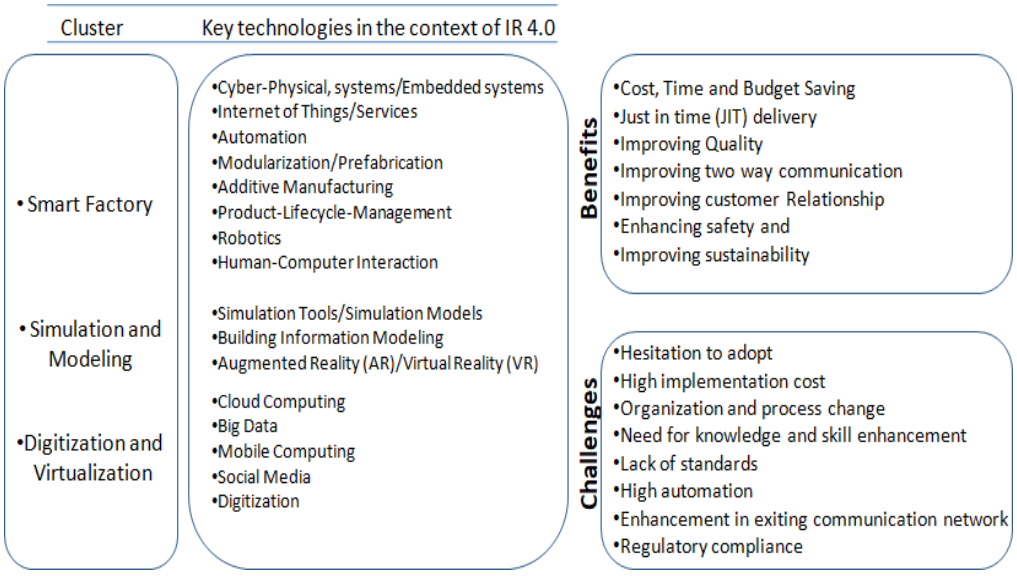


***Figure 2**. Benefits and challenges of adopting Industry 4.0 technology and concept cluster [11](Oesterreich and Teuteburg 2016).*

Unfortunately, major sectors of engineering and construction have not been able to keep up with the ever changing and adaptive revolution required for improved production and productivity. This not only halted their productivity, but also resulted in lack of progress

in labour efficiency [9]. This advancement of adaptation will not only connect the global development but will provide the ability to inverse the effects of the earlier industrial revolutions. Though, other industries have shown immense benefits by the application of the IR4.0. Additional to the third industrial revolution, industry 4.0 incorporates the adoption of IoT (Internet of Things), Cyber security, Augmented reality, Big Data, Autonomous robot, Additive manufacturing simulations, system integration and cloud computing as shown in figure 3. The goal transformation is to enable autonomous decision-making processes, monitor assets and processes in real-time, and enable equally real-time connected value creation networks through early involvement of stakeholders, and vertical and horizontal integration.

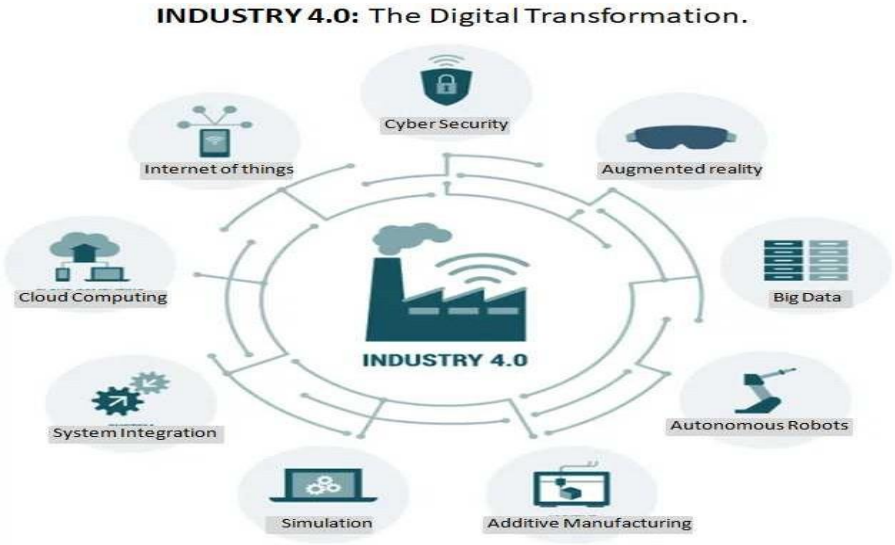


Figure 3: The digital transformation of industry 4.0

The construction sector has shown a great deal of hesitation to adopt this new concept. Construction industry is inundated with a few complications making IR4.0 incompatible for the industry. This situation is a result of a combination of complex internal and external factors ranging from unavailability of the right workforce, insufficient contractors, complexity, ambiguity, fragmentation, culture, and lack of knowledge to disintegration of the industry itself [12, 13]

Construction projects can be very multifarious due to multiple stakeholders in a solo project. The unpredictable environment surrounding the construction sector adds to the uncertainty of the project and the overall attitude of the industry is well recognized for reluctance towards adaptation [14]. Although, the construction industry carries immense potential, the only way forward to achieve maximum production efficiency and output is through the incorporation of new technologies, digitalization, and innovation for the construction industry. Incorporation of newly evolved tools of the industry that have already established themselves as successful aids to the construction industry like three dimensional scanning, use of drones, and information modelling have to be incorporated in the current practices and perceptions of the construction business the pathway chosen to deal with these difficulties will be significantly improved.

Materials and methods:

A quantitative research method was applied and the analysis of the result that were obtained through the questionnaires helped to formulate the results and draw the

conclusion of the whole project. Questionnaire were developed keeping in view that the respondents would be people mostly belonging to the construction industry and from various professional and educational backgrounds. The questionnaire was not only designed to collect the information and views related to the IR4.0 implementation in the construction industry but demographic data was also collected. This helps us to further explore the underlying causes of the delay and in-depth knowledge of restraints in the implementation of IR4.0. To ensure that only individuals related to the industry are approached, a list of the registered industrial professionals was obtained from the Engineering Council and Chamber of Commerce and Industry. All identified individuals were contacted for consent before moving forward with the implementation of IR4.0, its benefits and drawbacks in the construction sector in Pakistan were highlighted and discussed in detail.

A similar study conducted in Malaysia used Define, Measure, Analyse, Improve and Control (DMAIC) method [5] . All the underlying principles of DMAIC had an important role in the development of the questionnaire as the questions were designed around these principles and their understanding and application.

These responses were measured through a provided guide and scale to the respondents and data was collected. Analysis of the collected data was performed to interpret the results. Opportunities of improvement and control of the implementation of IR4.0 in the construction industry were further highlighted and explored through the participants and elaborated in this study. The position of the respondents, their understanding and knowledge related to IR4.0 in the construction sector was also measured. The responses were analysed and they depicted the experience of the respondents and an insight into the possibilities of the application of this industrial insurgency in the construction sector. Finally, the analysis also brought about recommendations that can be made through this study for the execution of IR4.0 in the construction industry of Pakistan and the possible outcomes related to this application.

The questions presented in this questionnaire related to the technological aspects of the IR4.0 were given a scale value where each respondent had to choose from a scale of 1-5. In this scale system 1 was graded for strongly differ, 2 was differ, 3 was not sure, 4 was agreed and 5 scale value was strongly agreeing to the technology in question. The data collected through the questionnaire was transferred into the statistical data analysis software. For the privacy of the respondents all the data was coded and a copy of the data was stored at a separate location following the international data protection protocols. Only the data analysis team was authorized to access the data for analysis and interpretation purposes. Statistical Package for Social Sciences (SPSS) was used for data analysis. The data was also imported into Microsoft Excel for parallel analysis and graphic presentations.

Results:

The main issues related to the successful implementation of the IR4.0 were identified through a process of thorough literature search and brainstorming with colleagues working in the construction industry. These issues were the base for making the survey questionnaires. The technologies related to IR4.0 in the construction industry were derived from the study by [11] Oesterreich and Teuteberg [14].

A total of 213 questionnaires were handed out to the industry professionals for evaluation. All of the returned forms were investigated further by a research team for any discrepancy and only completed valid responses were included to be compiled as the results of this study. Out of 213 questionnaires distributed only 140 valid responses were received. Table 1 details the survey questionnaire distribution, receiving, evaluation and

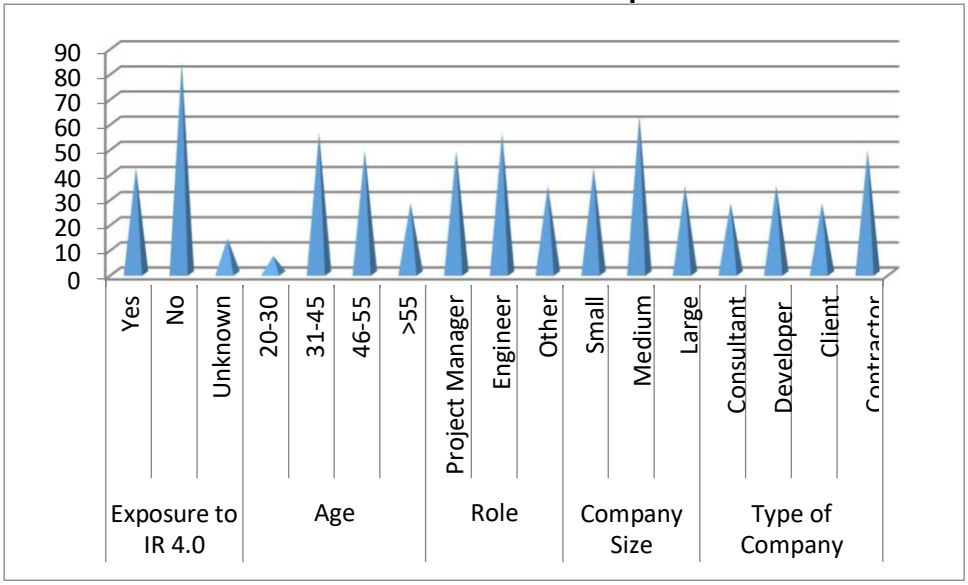
shortlisting details. These 140 responses were further statistically evaluated. The profile and the demographics of the respondents has been presented in Table 2.

Table 1

Questionnaire details

No:	Distributed	Received	Incomplete	Complete	Errors	Accepted
	213	195	21	174	34	140

Table 2: Profile of Respondents



As shown in Table 2, a major portion of the respondents were not aware of the IR4.0. The possible implementation in the construction industry accounted to a total of 84 out of 140 respondents which is 60% of the total respondents. 42 out of 140 which is 30% of the respondents have experience with IR4.0 during their professional career and the rest of 14 respondents making 10% of the total were unaware or unsure about their experience with technology in the construction industry that it would fall under IR4.0 implementation or not.

The professional positions that the respondents held in their companies was also a mix of various designations and departments. 35% were managers in various capacities and departments within the construction industry, 40% of the respondents were qualified engineers and the remaining 25% were people from other departments from within the construction industry related to manufacturing, planning and development.

Professional data of the respondents reveal that only 20% of them work as consultants in various organizations but majority, 35% work as independent contractors. 25% were developers in the construction industry and the rest 20% were clients of the industry.

An important insight into the responses through the questionnaires revealed an interesting aspect of the respondents understanding of the IR4.0 and its implementations

in the construction industry. The respondents who were not aware of the technologies associated to the IR4.0 being used in the construction business when further advised in the questionnaire about the list of the technologies that fall under this category changes their response and confirmed instead that they have experience with the IR4.0 technology changing the percentage to 40% of the respondents who had experience with IR4.0. This finding has been in line with similar findings in other studies found through literature search [15, 16][17].

The most commonly used technologies as per the respondents which fall under the umbrella of IR4.0 were social media, building management system and building information modelling followed by digitalization of the production, automation and prefabricated construction industry materials. Some of these technologies are already in use at various levels of the construction industry and have been recognized as carrying massive prospect in Pakistan for the flourishment of the construction sector.

Discussion:

The PESTLE analysis [17][18] was used to identify and analyze the critical components that may affect the successful implementation of the IR4.0 in Pakistan. These factors were included in the questionnaire and respondent's opinion related to each factor was considered and statistically analyzed. This research survey also provided an insight into the matters related to the application of IR4.0 in the construction business of Pakistan which directly or indirectly affect the success and adaptation of the industry to the emerging technologies. The factors included in the PESTLE analysis are Politics, Economic, Social, Technology, Legal and Environment. The identified challenges related to each factor have been summarized in Table 3 below. The respondents were also given the option to provide feedbacks on the opportunities available in Pakistan in the construction business related to the IR4.0 implementation. The summarized responses are presented in Table 3 below.

PESTEL	Challenges	Opportunity
Political	A challenging factor posed by the existing environment in the construction industry would require an enormous political participation and commitment. This will not only provide necessary provisions for the implementation of IR4.0 but will also be a necessary factor for an ongoing governance and success.	Implementing IR4.0 in the construction industry in Pakistan can provide a huge opportunity for the sector to follow and compete in the developed world. Through IR4.0 the construction industry can manage to bring in the necessary changes and produce results as that of the rest of the world.

Economic	Implementing IR4.0 in the construction industry in Pakistan would be a costly affair and will not be possible without hefty financial commitment from public and private sectors. These huge financial and economic investments can attract irregularities and would require a transparent system with a set level of accountabilities.	Economic effects of the IR4.0 can be very assertive. There would be a new industrial set up, with jobs created which will add on to the benefits of IR4.0 to the sector.
Social	The predominantly old-school methods prevailing in the construction industry would have to be addressed and rectified. Relevant trainings and education would have to be provided.	This will provide an opportunity to the industry to steer away from the traditional methods and incorporate technology providing an opportunity to up skill the existing manpower and also to change the mind set through innovation and technology.
Technological	There would be many technical challenges for implementing IR4.0 in Pakistan's construction sector. Existing system should be incorporated with new technologies, new equipment in industry has to be installed and a new technical specification realm would have to be introduced.	Technically the IR4.0, if implemented in the construction industry in Pakistan, can bring about many production changes that will aid mass production, reduce the time of delivery for construction equipment and material, and will also help the end user in terms of ease of use.
Environmental	Organizational changes have to be brought forward at all levels of the industry which will require changes at bottom, middle and higher levels. Decision makers would have to address all the concerns brought forward by the industry leaders.	Through the use of advanced technologies, the greenhouse gas emissions can be reduced for the whole construction industry by providing sustainable and environment friendly solutions.
Legal	Best Practice, laws and regulations have to be introduced for the construction sector for the implementation and incorporation of IR4.0 into the industry.	Once the IR4.0 is introduced to the construction sector new laws related to the construction industry could be formulated, which will further help the industry to flourish.

IR4.0 is dissimilar to the preceding industrial revolutions. The previous three, while massively impacting the human world through the innovative introduction of the concepts they carried, IR4.0 came out differently and provided a concept of amalgamation of the existing world with that of the emerging and developing information technology world. The core principle of this industrial revolution relied and focused on cyber-physical system approach [18].

IR4.0 is the integrated industrial approach promoting and endorsing smart manufacturing. This changed the emphasis of companies and management authorities

involved in product manufacturing towards integration of machines and devices with more complex function, development and application of software for better quality production and quality assurance. It provides better control and forecast beneficial outcomes not only for the business but also for the society and the environment [19].

The integration of all these independent but integrated units is known as the Internet of Things (loT). It is responsible for the evolution of the technology transforming the product design, use, fabrication, maintenance and operation. Construction automation technologies have been introduced utilizing the robotic techniques for the production of building constituents and materials [15]. This change and understanding of the professionals regarding IR4.0, its possible opportunities in the construction industry of Pakistan needs to be addressed. As better understanding will yield better results and will definitely create an environment where new and emerging technologies will be integrated into the prevailing construction industry in Pakistan. This will aid the industry to minimize the waste of important resources and will not only maximize the profits and productions but will also have positive societal and environmental effects.

IR4.0 has proven to be an immense challenge for the construction industry globally. Particular to Pakistan where technological digitalization will not only increase the production capability of the industry but will also aid to decrease the gap between the construction industry and the digital world. This adaptation and implementation of IR4.0 in the construction industry will also bring about the necessary and much needed positive environmental effects to the struggling global and national environment. While some technologies included in the IR4.0 have been completely developed through trials and testings, some are still in the progress of development.

Pakistan's construction industry can use this to advantage and explore venues through this technological advancement which will foster increased employment opportunities and future sustainability. A very important aspect to consider is the construction manufacturing which will be highly impacted by the implementation of the IR4.0 and will require a lot of strategic decision making, vision and commitment on all levels of decision-making process. Through the implementation of IR4.0 in the design, manufacturing and construction process, the quality and quantity of the industry can be improved massively which will attract investors into the industry and help to flourish the construction industry.

Conclusion:

Construction industry in Pakistan has great potential for expansion and investment and is full of opportunities for improvement. Unfortunately, like the rest of the world the construction sector in Pakistan has been reluctant in adopting and adapting to the emerging digital world and incorporating the upcoming technologies into the industry. Although being part of the same industry there is a huge gap between the construction manufacturing and the construction industry, which in turn is barrier in the implementation of IR4.0 in the industry itself.

IR4.0 has been introduced into the construction industry for a while, but complete implementation and adaptation is still a far reached goal especially in Pakistan. Construction industry is lacking massively, although many of the technologies are readily accessible and being partly used in one way or the other within the industry. There are many challenges in the path of full implementation of IR4.0 in the construction industry in Pakistan but at the same time there are hugely tremendous opportunities as well. These opportunities need to be identified and utilized to enhance the industry's potential.

The identified risk factors in this study should be carefully implemented in the construction industry. By this, it can compete with the global construction industry and with

other industrial counterparts where IR4.0 has been successfully implemented. Further exploration of the findings is also highly recommended, utilizing study designs focusing on the identified factors. These studies will be able to pay a vital role for the implementation of IR4.0 in the construction industry in Pakistan.

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