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Industrial Revolution (IR) 4.0 in the Construction Sector: Exploring the Possibilities in Pakistan

Mirza Hammad Ghazanfar Baig[1], Muhammad Mutasim Billah Tufail[2], Mirza Jawad Ghazanfar Baig[3], [1,2]Department of Management Studies Bahria University Karachi Campus Pakistan.

Construction in Pakistan is a flourishing and booming industry with significant economic impact. Like most of the world, the construction industry in Pakistan has failed to implement and incorporate the Industrial Revolution (IR) 4.0 and has not been able to yield the fruitful affects brought forward through this revolution. Though relying mostly on traditional ways and technologies, the industry has been able to deliver projects ranging from private residences to mega commercial sites. This study was conducted to evaluate the challenges and possibilities faced by the construction sector in terms of the IR 4.0 implementation. Industry professionals were approached and their opinions and understanding of the IR 4.0 were evaluated. Despite being the third largest industry of the world, construction sector is still lacking in the adaptation of advance digital technology, this sector presents a huge potential for IR 4.0 implementation and if successfully incorporated into the existing system will make the industry more productive and efficient.

Keywords: *IR 4.0, Construction Sector, IR 4.0 Opportunities and Challenges, IR 4.0 Adoption in Pakistan.*

Introduction; The first three Industrial Revolutions

The last few decades have seen the world having evolved and achieved far beyond what it has achieved previously. The transition of the population from a 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 (Maskuriy et al, 2019).The demand for affordable housing was inevitable and has risen to levels the world has not seen before (Adabre and Chan, 2019) associated with a simultaneous requirement of social, utilities and transportation infrastructure.

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 to the environmental effects in growing urban centres. The construction industry has been able to ensure a reduction in cost of the housing and implements environmental friendly tactics through efficient usage of uncommon resources and constructing buildings ensuring co-efficiency (de Wilde, 2019). These achievements influence the economy positively with an insurance that the global infrastructure gap is constricted and the overall economy has been able to boost and flourish.

Since the beginning of industrialisation in the 1700s, the 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 industry revolution occurred in the 1870s, when the power sector was revolutionised 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, industries were able to achieve the dream of mass production which they had been struggling and trying to achieve (Alaloul et al, 2020). 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.

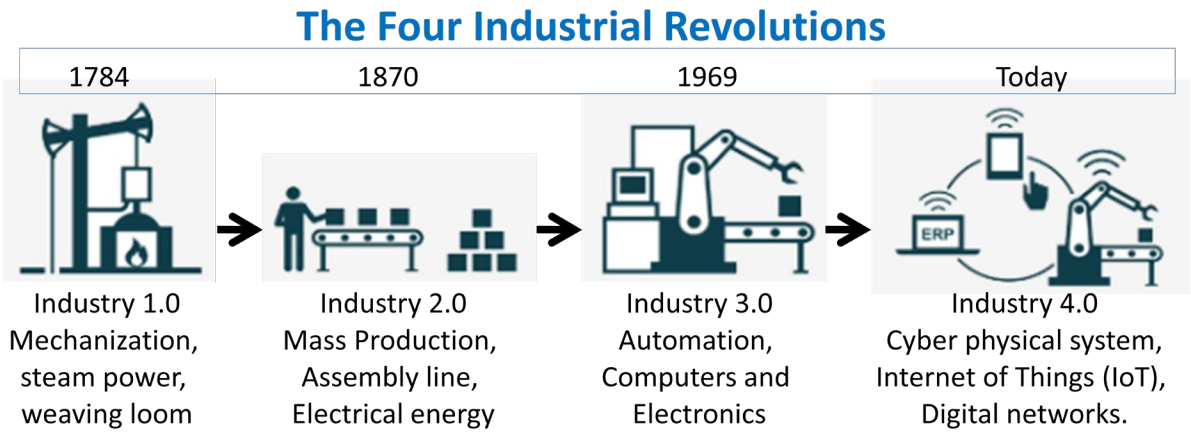

Figure 1: The Industrial revolution 4.0.

Industrial Revolution 4.0:

The Fourth Industrial Revolution (IR 4.0) is based on and linked to the digital insurrection, which connects technology and 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 (Philbeck and Davis, 2018). IR 4.0 is not limited to

the incorporation of new technology but it also supports sustainability (Hidayatno, Destyanto, and Hulu, 2019) with energy and energy efficiency, going hand in hand as major contributing factors (Lemaire, 2019). The implementation of innovations for energy efficiency is very hard (Upadhyaya, 2013) and renewable energy consumption still floats around 19.2% (Conti, 2016).

The IR 4.0 stresses upon the viability and sustainability of the whole manufacturing process and has an advanced mechanism of the convolution to integrate the production as well as the product practices (Kagermann,Wahlster and Helbig, 2012) to becoming part of a sustainable system Demartini et al, 2017). The Industrial Revolution 4.0 has been recognised as a term for the development of the manufacturing industrial sector in Germany, which was meant to embrace automation and data exchange (Alaloul et al, 2020).

Similar to the manufacturing sector, the construction sector can also be an important beneficiary of the IR 4.0. The implementation of IR 4.0 will ensure that production efficiency will be achieved through the utilisation of the advanced technologies like mechanised automation that can 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. Oesterreich and Teuteburg (2016) have identified numerous benefits of adopting the fourth revolution in the construction industry. They categorised the implementation mechanism into three clusters; Smart Factories, Simulation and Modelling, and Digitisation and Virtualisation, as shown in figure 2.

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 has not only halted their productivity but also resulted in lack of progress in labour efficiency (Livotov et al, 2019). 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. Although, other industries have shown immense benefits by the application of the IR 4.0.

The construction sector has shown a great deal of hesitation to adopt this new concept. The construction industry has a few complications that make IR 4.0 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, inefficient contractors, complexity, ambiguity, fragmentation and cultural lack of knowledge to the disintegration of the industry itself (Oesterreich and Teuteberg, 2016; Craveiroa et al, 2019)

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 recognised for reluctance towards adaptation (Alaloul, Liew & Zawawi, 2016). However, the construction industry carries immense potential: the only way forward to achieve maximum production efficiency and output is through the incorporation of new technologies of digitalisation and innovation for the construction industry. Incorporation of newly evolved tools of the industry that have already established themselves as successful aids the construction industry; three dimensional scanning, the use of drones, and information modelling have to be incorporated in the current practices to yield supreme benefit (Gao, Koch & Wu, 2019).

The goal of this study is to recognise the challenges of employing pioneering technology, exploring possibilities in the future, and the effective application of IR 4.0 in the construction business in Pakistan. Through the understanding of the existing practices and perceptions of the construction business, the pathway chosen to deal with these difficulties will be significantly improved.

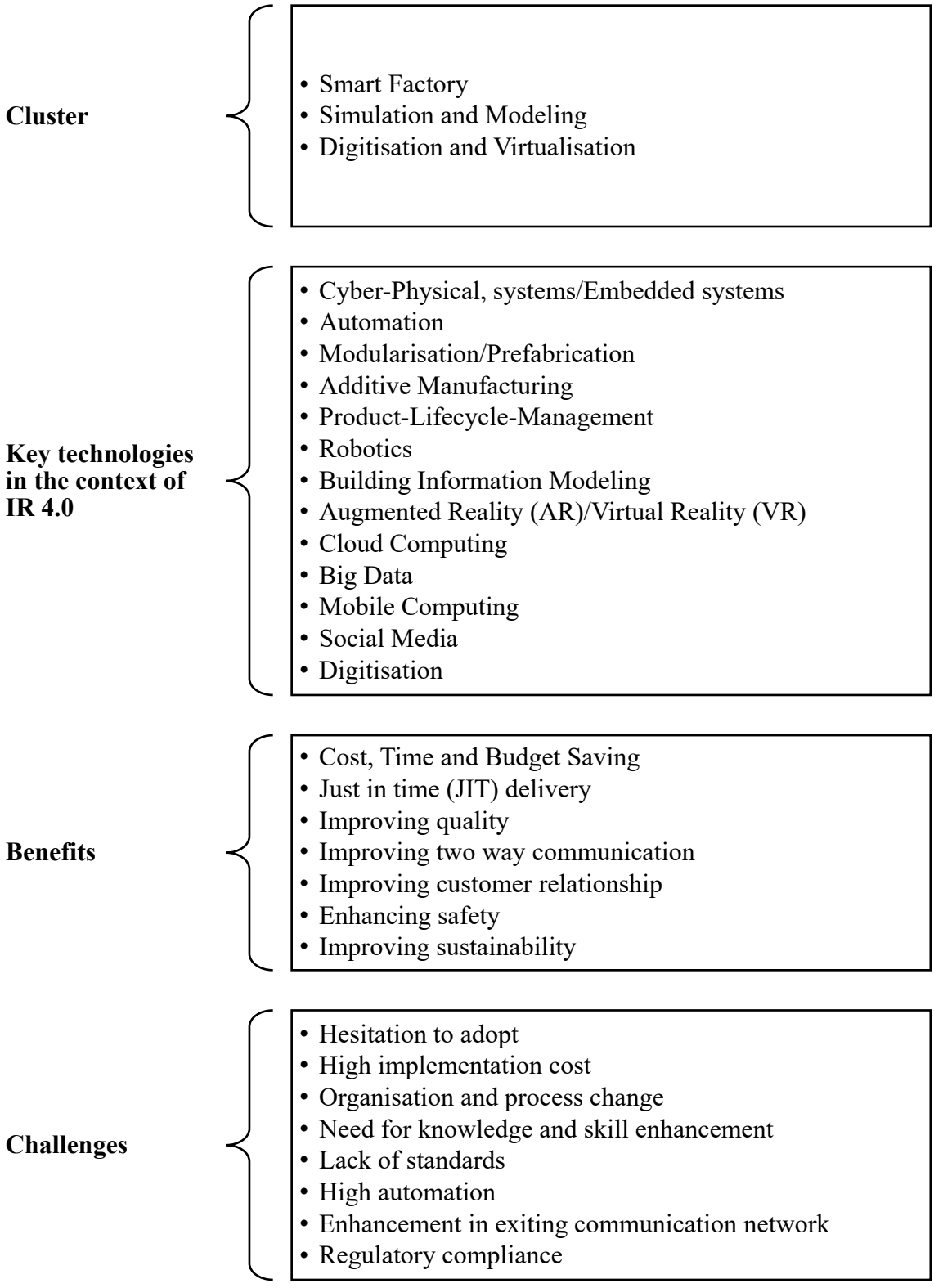

Figure 2. Benefits and challenges of adopting Industry 4.0 technology and concept cluster (Oesterreich and Teuteberg 2016).

Materials and methods:

A quantitative research method was applied and the analysis of the results that were posted through the questionnaire helped to formulate the results and draw the conclusion of the whole project. A questionnaire was 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 IR 4.0 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 individuals related to the industry are approached only, 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 sending out the questionnaires. The changes that can be brought forward through implementation of IR 4.0, its benefits and drawbacks in the construction sector in Pakistan, were highlighted and discussed in detail.

A similar study conducted in Malaysia used the Define, Measure, Analyse, Improve and Control (DMAIC) method (Alaloul et al, 2020). 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.

The 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 IR 4.0 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 IR 4.0 into the construction sector, was also measured. The response was analysed, which 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 IR 4.0 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 IR 4.0 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 was strongly agreeing to the technology in question.

The data collected through the questionnaires 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 authorised to access the data for analysis and interpretation purposes. The 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 IR 4.0 were identified through a process of thorough literature search and brainstorming with colleagues working in the construction industry. These issues were the base for creating the survey questionnaires. The technologies related to IR 4.0 in the construction industry were derived from the study by Oesterreich and Teuteberg (2016)

A total of 213 questionnaires were handed out to the industry professionals for evaluation. All the returned forms were investigated further by a research team for any discrepancy and only completed valid responses were included to compile the results of this study. Out of 213 questionnaires distributed only 140 valid responses were received. Table 1 details the survey questionnaire distribution, receipt, evaluation and shortlisting details. These 140 responses were further statistically evaluated. The profile and 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 the respondents

Feature	Selection	Total	Percentage
Exposure to IR 4.0	Yes	42	30
	No	84	60
	Unknown	14	10
Age	20-30	7	5
	31-45	56	40
	46-55	49	35
	>55	28	20
Role	Project Manager	49	35
	Engineer	56	40
	Other	35	25
Company Size	Small	42	30
	Medium	63	45
	Large	35	25
Type of Company	Consultant	28	20
	Developer	35	25
	Client	28	20
	Contractor	49	35

As shown in table 2, a major portion of the respondents were not aware of IR 4.0. The possible implementation in the construction industry accounted to a total of 84 out of 140 respondents, which is 60 percent of the total respondents. Of the respondents,42 out of 140 or 30 percent have had experience with IR 4.0 during their professional career and the remaining14 respondents at 10 percent of the total were unaware or unsure about their experience with technology in the construction industry, whether 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. Managers in various capacities and departments within the construction industry comprised 35 percent, 40percent of the respondents were qualified engineers, while the remaining 25percent were people from other departments from within the construction industry related to manufacturing, planning and development.

Professional data of the respondents reveal that only 20percent of them work as consultants in various organisations but a majority, 35 percent, work as independent contractors. Developers in the construction industry counted for 25 percent and the remaining20percent 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 IR 4.0 being used in the construction business, when further advised in the questionnaire about the list of the technologies that fall under this category, changed their response and confirmed instead that they have experience with the IR 4.0 technology, changing the percentage to 40percentof the respondents who had experience with IR 4.0. This finding has been in line with similar findings in other studies found through the literature search (Sommer, 2015).

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 digitisation 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 recognised as carrying massive prospect in Pakistan for the flourishment of the construction sector.

Discussion:

The PESTLE analysis (Perera, 2017) was used to identify and analyse the critical components that may affect the successful implementation of the IR 4.0 in Pakistan. These factors were included in the questionnaire and a respondent's opinion related to each factor was considered and statistically analysed. This research survey also provided an insight into the matters related to the application of IR 4.0 in the construction business in 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 summarised in table 3. The respondents were also given the option to provide feedback of the opportunities available in Pakistan in the construction business related to the IR 4.0 implementation. The summarised responses are presented in table 4.

Table 3: Challenges in the construction sector for IR 4.0 in Pakistan PESTLE analysis

Challenge	Influence	Summary
Political (P)	Control/ Governance	A great challenge posed by the existing environment in the construction industry would require a huge political participation and commitment. This will not only provide necessary provisions for the implementation of IR 4.0 but will also be a necessary factor for an ongoing governance and success.
Economical (E)	Accountability/ Transparent system	Implementing IR 4.0 in the construction industry in Pakistan would be a costly affair and will not be possible without heavy financial commitment from private and government sectors. These huge financial and economic investments can attract irregularities and would require a transparent system with a set level of accountabilities.
Social (S)	Culture	The predominantly old school methods prevailing in the construction industry would have to be addressed and rectified and appropriate training and education would have to be provided.
Technological (T)	Technical	There would be many technical challenges for implementing IR 4.0 in Pakistan's construction sector. New technologies have to be introduced and incorporated into the existing system, new equipment and industry has to be installed and a new technical specification realm would have to be introduced.
Environmental (E)	Organisational	Organisational changes have to be brought forward at all levels of the industry which will require changes at bottom, middle and higher levels, as well as decision makers would have to address all the concerns brought forward by the industry leaders.
Legal (L)	Laws and Regulations	New laws and regulations have to be introduced for the construction sector for the implementation and incorporation of IR 4.0 into the industry.

Table 4: Opportunities in the construction sector for IR 4.0 in Pakistan PESTLE analysis

Challenge	Influence	Summary
Political (P)	Industrial Revolution	Implementing IR 4.0 in the construction industry in Pakistan can provide a huge opportunity for the sector to follow and compete in the developed world. Through IR 4.0 the construction industry can manage to bring in the necessary changes and produce results as that of the rest of the world.
Economical (E)	Economic boost	Economic effects of the IR 4.0 can be very assertive. There would be a new industrial set up, with jobs created which will add on to the benefits of IR 4.0 to the sector.
Social (S)	Work culture change	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(T)	Production	Technically the IR 4.0, if implemented in the construction industry in Pakistan, can bring about many production changes thatwill 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(E)	Sustainable solution	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 (L)	New Laws and Regulations	Once the IR 4.0 is introduced to the construction sector new laws related to the construction industry could be formulated, which will further help the industry to flourish.

Industrial revolution 4.0 is dissimilar to the preceding industrial revolutions. The previous three massively impacted the human world through the innovative introduction of the concepts they carried, while IR 4.0 came out differently and provided a concept of an amalgamation of the existing world with that of the emerging and developing information technology world. The core principle of this industrial revolution relied upon and is focused on the cyber-physical system approach (Alaloul, 2019)

IR 4.0 is the integrated industrial approach promoting and endorsing smart manufacturing. This has changed the emphasis of companies and management authorities involved in product

manufacturing towards an integration of machines and devices with more complex functionality, and the development and application of software for better quality production and quality assurance. It provides better control and forecast of beneficial outcomes not only for business but also for society and the environment (Maresova, 2018)

The integration of all these independent but integrated units is known as the internet of things (IoT). It is responsible for the evolution of the technology transforming the product design, use, fabrication, maintenance and operation. Construction automation technologies have been introduced utilising robotic techniques for the production of building constituents and materials (Bock, 2015).

This change and understanding of the professionals in regards to IR 4.0, and its possible opportunities in the construction industry of Pakistan, needs to be addressed. 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 minimise the wastage of important resources and will not only maximise the profits and production but will also have positive societal and environmental effects.

IR 4.0 has proven to be an immense challenge for the construction industry globally and particularly in Pakistan where technological digitisation will not only increase the production capability of the industry but will also help decrease the gap between the construction industry and the digital world. This adaptation and implementation of IR 4.0 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 IR 4.0 have been completely developed through trials and testing, some are still in the process of development.

Pakistan's construction industry can use this to its advantage and explore avenues through this technological advancement that 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 IR 4.0 and will require a lot of strategic decision making, vision and commitment on all levels of the decision-making process. Through the implementation of IR 4.0 in the design, manufacturing and construction process, the quality and quantity of the industry can be improved massively, which will attract investors to the industry and help the construction industry flourish.

Conclusion:

The 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. And although

being part of the same industry, there is a huge gap between the construction manufacturing and the construction industry, which in turn is a barrier tothe implementation the IR 4.0 in the industry itself.

IR 4.0 had been introduced into the construction industry for some time but complete implementation and adaptation is still beyond the bounce, especially in Pakistan. The construction industry is lacking significantly in this, even though many of the technologies are readily accessible and being partly used in one way or another within the industry.

There are many challenges in the path of full implementation of IR 4.0 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 utilised to enhance the industry's potential.

The identified risk factors in this study should be carefully analysed and immediately addressed so that IR 4.0 can be successfully implemented in the construction industry. By this it can compete with the global construction industry and alsowith other industrial counterparts where IR 4.0 has been successfully implemented. Further exploration of the findings is also highly recommended utilising study designs focusing on the identified factors. These studies will be able to play a vital role for the implementation of IR 4.0 in the construction industry in Pakistan.

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