Evaluation of Constraints for implementing Industry 4.0 practices in Construction Projects

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***Abstract*— Industry 4.0 is one of the burgeoning concepts among the academicians and practitioners around the world. It is basically a synonym for fourth Industrial revolution that reflects the novel and dynamic technologies that have the huge potential to fully automate the production processes in construction projects by connecting the physical and virtual world. It creates a seamless network by using cyber physical systems (CPS) acting as a platform to connect IOT and IOS etc. The construction Industries possessing the knowledge of Industry 4.0 and its applicability, hesitate and are notoriously showing resistance in contrast with advanced Industries towards the implementation of Industry 4.0. This resistance is because of the potential constraints that emerge during its implementation phase. The association of the constraints is due the complex and interoperable characteristics of its novel technologies. So, it is necessary that irrespective of the benefit, the associated potential constraints need to be identified, addressed and evaluated in a rational and logical way. Their evaluation will support us to fulfill the gap of perfect framework for its satisfactory implementation in construction projects.**

Index Terms: **Industry4.0, Constraints, Practices, Implementation, Construction Industry, Framework.**

I.INTRODUCTION

The Industry 4.0 concept is the result of the technological progress of the Fourth Industrial Revolution[1]. The concept of Industry 4.0 is not basically new but has its origin as a part of academic research from many years with different perceptions.The expression "Industry 4.0" was presented in 2011 by Henning Kagermann, educator of material science and previous leader of the SAP(Systems Applications and Products in Data Processing) board, and developed into a procedure[2]. It is a term that is well accepted in industrial sector also[3]. The general proficiency of modern worth creation is relied upon to increment, alongside biological and social advantages, e.g., decreased energy and material utilization, squander decrease, and versatile workplaces[4–6].Industry 4.0 has an exceptionally complicated arrangement of design for assembling, accordingly, powerful execution is a subject of exploration[7].The beginning stage for Industry 4.0 is the idea of the shrewd production line (Smart Factory), the brilliant business (Smart Industry), the savvy mechanization (Smart Automation), and progressed fabricating or advanced manufacturing[8,9]. Initially the concept of Industry 4.0 originated from Germany in 2011. The scientists referred it as a way of increasing automation of industrial processes and the connectivity between physical and virtual world. The German Government accepted the concept and adopted industry 4.0 as a strategy for industrial production and development. Later the concept is evolved and is now expressed as Fourth Industrial Revolution that reflects all the complex technologies associated with it and used in an organization. In order to generate a new quality of production this novel innovative approach may be very fruitful. Currently, there is not a single universally recognized definition of Industry 4.0 but its understanding is based on a combination of interconnected characteristics and interoperability of advanced digital technologies that distinguishes Industry 4.0 practices both in manufacturing and relevant economic sectors. The development of CPS (cyber physical systems), IOT (internet of things), IOS (internet of services), process automation and system integration help in merging the real and the virtual world that lead to the real-time data exchange between people and objects along the entire value chain[10].

The advances in mechanization and correspondence advancements like web of things (IoT), cloud registering (cloud computing), large information and investigation(big data and analytics), made this joining conceivable through cyber physical frameworks (CPS)[7].The explicitness of I4.0 results from process robotization, framework reconciliation, Internet of Things (IoT), Internet of Services (IoS), and the improvement of digital actual frameworks (CPS)[9,11,12].These frameworks blend the genuine and the virtual world and empower information to be moved among individuals and items along the whole worth chain progressively[6,13].Savvy associations of independent, complete constructions comprising of machines and self-arranging ongoing creation frameworks are relied upon to prompt sensational upgrades in productivity, better asset the executives and more prominent adaptability and flexibility of items and administrations, dynamic proficiency, better danger control, and a more noteworthy business outreach[6,14–16]. Industry 4.0 depends on the reception of computerized advances to accumulate information continuously in real time and to break down it, giving valuable data to the assembling framework[17]. By considering the similar approaches that are developing worldwide the Industry 4.0 can be defined as *"A real-time intelligent, horizontal, vertical networking of actors (people), machines, objects, information and communication systems with the aim of dynamically controlling complex systems*[6,11]*."*

It can also be described as the transformation at a radical level of intellectual creativity that has a huge potential to enhance and improve the communication between products, their environment and business partners so that goals are accomplished in an increasing digitized and automated manufacturing environment by creating the digital value chains[18].

Accordingly, Industry 4.0 was viewed as the means for independent tasks of cycle from assembling to support areas. Also, it has degree to diminish the work packed organizations into development driven endeavors and make enormous scope assembling to high combination creation. Further, the impact of Industry 4.0 has wide open entryway from social protection to correspondence industry; improvement to get together industry; and coordination to defend industry. It is clear that Industry 4.0 is a heap of innovations, which organizations can take on for business greatness[19].

The principle spaces of the effect of I4.0 include: competitiveness and business models[5,20,21]; efficiency and performance[11,22–24]; workforce related factors[11,25,26]; and consumer needs[16,27]. The main idea of scientists behind the implementation of Industry 4.0 is to digitize and develop the intelligent, integrated and fully autonomous factories called Smart or Dark factories. This smart manufacturing permits to build quality, efficiency and adaptability and can assist with accomplishing tweaked items at an enormous scope and in a sustainable manner with better asset utilization. Industry 4.0 additionally considers the trading of data and incorporation of the inventory network (called Smart Supply Chain), synchronizing creation with providers to lessen conveyance times and data contortions that produce bullwhip results. This mix likewise empowers organizations to consolidate assets in cooperative assembling, permitting them to zero in on their center skills and offer abilities for item advancement in industry stages, a joint work to create items and corresponding resources and administrations, with more worth added. This smart concept will give rise to the wearable and implanted technologies and it is expected that in 2025 1million core sensors of Industry 4.0 will be implanted in human life[3,17]. The smart products can provide new services and solutions to the costumer and feedback for the development of new products. This is the reason why a few scholars consider the smart products as the second main objective of industry 4.0, since these products permit new plans of action, for example the item administration frameworks, which set out new open doors for makers and specialist organizations[28,29]. As per global report of 2017 the global spending in construction was $11 trillion and is projected to increase by $14 trillion in 2025[30].

II. LITERATUREREVIEW

This paper has conducted an extensive review of the most recent articles on industry 4.0 and also provides review of some articles on past three driving industrial revolutions to get their idea in brief. This paper provides the opportunities for future research work also. From the concept of inequalities and living standards in the world or in the societies, we

can get the broader idea to know the historic lesson of Industrial Revolution[31]. The product of a million small beginnings is the first industrial revolution. The first IR was the shift from human and animal labour technology into machinery[32,33]. The Industry 2.0 "The Age of Synergy" by Vaclav Smith was a period of invention of new technologies like electricity, internal combustion engine, the chemical industries, alloys, petroleum, electrical communication(through telegraph, telephone and radio), and running water with indoor plumbing[34]. The embedded systems, smart objects, cyber physical systems (CPS), the thought of Smart or Dark Factory, robust network, cloud computing, and IT security will become the technological cornerstones for future manufacturing and production processes[35].The construction management tools such as WBS(work breakdown structure), CPM(critical path method), EVM(earned value management) etc. are unable to tackle the dynamic construction projects and currently BIM is the core technology supporting the idea of Industry 4.0 in construction projects[36]. The formation of digital twin provides a near real-time connection between the physical and digital world which is only possible by integrated BIM with the novel technologies of Industry 4.0 like IOT, VR etc. BIM is unable to do it alone[37].

In case of building construction projects VR and AR are investing a popular role in minimizing the gap between the digital (e.g. 3D models, simulation model etc.) and real world (position or conditions of materials, equipment's)[30].

From the UK based construction company case study, the view shared across the conversation represents a significant new opportunity of Virtual Reality (VR) adoption, BIM and digital twin of construction and their use for active interaction through Virtual Reality (VR) and simulation of activity prior to on site construction that is being explored. This case study revealed that future of 14 adoption and implementation lies in prefabrication and advanced manufacturing and engineering, combined with a digital twin[38]. Notwithstanding various instances of the execution of Industry 4.0 in endeavors, there is no broad system for the execution of Industry 4.0 with a definite timetable. Exploring the methods of executing Industry 4.0 is as yet an ebb and flow and neglected space of exploration[1].The industry 4.0 idea has an exceptionally mind-boggling innovation design of the assembling frameworks (Lee et al., 2015), which is one of the fundamental worries in this new modern stage. Subsequently, the powerful execution of Industry 4.0 advancements is as yet a subject of exploration (Lee et al., 2015; Babiceanu and Seker, 2016; Dalenogare et al., 2018). Some earlier works have proposed development models for the execution of these advancements (for example Schuh et al., 2017; Lee et al., 2015; Lu and Weng, 2018; Mittal et al., 2018), while different works have concentrated on the effect of these innovations on modern execution (Dalenogare et al., 2018). Notwithstanding, there is an absence of studies giving observational proof with regards to the manner in which these innovations are taken on in assembling organizations, prompting a significant inquiry: what are the current Industry 4.0 advances reception designs in assembling organizations?[17]. The Industry 4.0 idea is bit by bit carried out in enterprises through speculation projects, implemented in portions in chosen spaces of movement[39].The methods of implementing Industry 4.0 in ventures have not yet been depicted exhaustively in a thorough and smaller way in the literature[40]. The selectivity of carrying out mechanical arrangements average for Industry 4.0 happens both in assembling organizations and in person businesses[41–43].

The connectivity of constraints is not manmade; the design engineers always deal with constraints like time, weight and operability as they exist in real sense **(**Senge, et.al 2001**).**Sendler and Kagermann 2013stated that cyber physical systems (CPS) along with IOT and IOS will be the basis for the evolution from third to fourth phase of industrialization.The transformation of digital engine of internet and creation of virtual environment i.e., work is now possible through cyberspace or in the dimensions of space and time (Robert, B.H 2015). Oesterrich and Teutebergin 2016 stated that major components of Industry 4.0 like Internet of Things (IOT) Internet of Services (IOS), Cyber physical systems (CPS), Big Data, and Cloud Computing. Robotics etc. are now getting attention to digitalize Construction Industry though their pragmatic applications in construction are still at lower level. The internet of everything (IOE) is formed when machines, devices, sensors and humans are connected via IOT and IOS. With this human-human interaction, machine-machine

interaction and human- machine interaction is achievable (Hermann, et.al 2016). A deeper and core understanding of fundamental concepts and technologies are needed particularly in the process of implementation of 4.0 practices. The industry 4.0 implementation is the manifestation of "smart thinking" approach in manufacturing and production ecosystem (Bartodziej, C.J.2017). According to Chiarello et.al 2018the industry 4.0 is still a burgeoning research subject and currently, it can be perceived as the convergence of different concepts and novel technologies. Irrespective of the benefits like producing quality products at optimized cost and time, it is important to understand and address the critical constraints that are specific to building construction projects (Paper, C.; Nadeem, A. 2019).The economic implementation cost, lack of knowledge, acceptance of technology, individual hesitance and high requirement for construction equipment maintenance and process are the barriers identified in past years (Diana, I.; Aripin et.al2019).The defined methodologies of Industry 4.0 aim at the transformation of machine dominant manufacturing to digital manufacturing (Oztemel, E.; Gursev, 2020**)**.Maria Kozlovska et.al 2021stated that there are some research gapes in exploring the synergy effects of 4.0 technologies to optimize the benefits and meet the future challenges.

III. FINDINGS

The construction industries are now aware about the applicability of these 14 in augmenting the business but in contrast with advanced industries, the construction industry hesitate and notoriously showing resistance towards the adoption of innovation and technologies due to perceived exorbitant costs of 14, training resource requirement, unwillingness to learn and demolish old traditional systems, processes and procedures[38].

The concept of implementing the Industry4.0 would help in relieving the pressure, if it is adopted by removing the barriers efficiently. Some of the potential constraints identified in construction projects during past years have been presented[18].

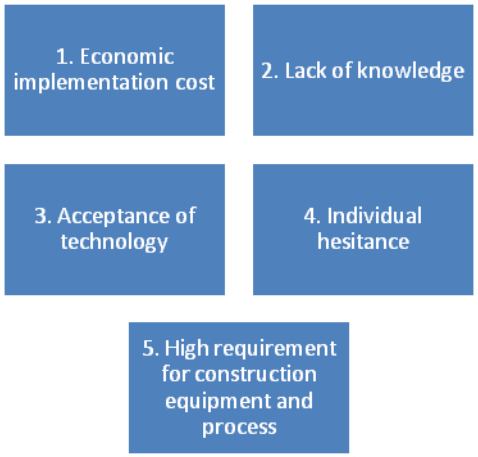

Figure1. Identified critical constraints for implementing Industry 4.0 practices

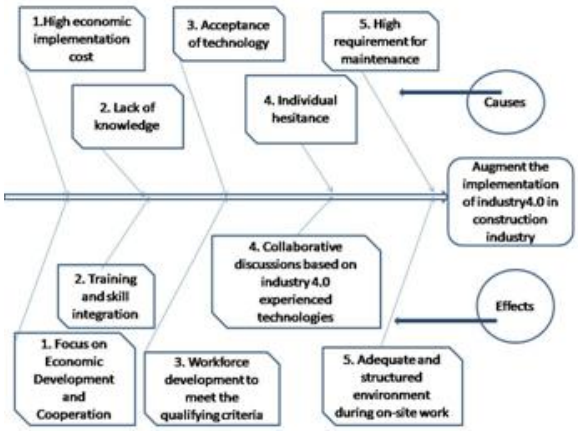

Figure 2. Cause and Effect Diagram for Industry 4.0 implementation

It is obvious that without stringent monitoring the deployment of Industry 4.0 in construction projects will not give fruitful results. In order to make the effective and successful implementation of 4.0 novel technologies, there is a dire need of integration of firms and 4.0 interoperable technologies. The BIM in combination with VR will create new possibilities for developing an efficient communication platform. Their combination can also create a risk-free training environment for visualized labor training, skill transfer, and safety education. The VR based real time construction model can be used for the safety training, especially for workers performing their work at huge heights. For supporting constructability analysis meetings Boton proposed a VR based collaborative BIM 4D simulation framework[36]. With the extensive growth of digitalization ethical and sociological issues may arise in the construction industry[37]. The potential risks associated with VR are dizziness and nausea[44].The construction industry

doesn't remain specific to its special applications like BIM, 3D printing or modularization of construction components but it had adopted the new technologies like IOT, simulation, autonomous systems, robots, AR, additive manufacturing and big data from Industry 4.0 except cyber security. BIM, mobile computing, cloud computing or modularization has reached market maturity. Additive manufacturing, AR, VR and Mixed Reality are still at the prototyping stage[37].

IV. RESEARCH GAPS

1. Will the empirical study guarantee the success of Industry 4.0 adoption in construction projects to give successful results[45]?
2. Would construction industry be able to adopt all key pillars of Industry 4.0 at the market maturity level?
3. There is a dire need to explore the synergy effects of novel key technologies of Industry 4.0 in construction projects to optimize the benefits and meet the future challenges.

V. BENEFITS (Local and Technical)

LOCAL BENEFITS

1. Meeting individual customer requirements: Industry 4.0 clears a path for singular, client-arranged criteria to be incorporated into the requesting, outline, setup, arranging and produce and also activity stages and requests a minute ago changes to be fused. Industry 4.0 permits the fabrication of coincidental things that have low creation volumes while as yet making a benefit[47].
2. Flexibility: The CPS-based uniquely delegated frameworks organization allows the dynamic course of action of different pieces of business structures, which join quality, time, strength, danger, cost and eco-invitingness. This accordingly makes a way for "managing" of materials and furthermore supplies chains. It can similarly be fathomed that while building methods can be made more planned, creating techniques can be changed, brief lacks (for example due to supply issues) can be changed and tremendous additions in yield can be found in a short space of time[48].
3. Optimized decision taking: Winning in the overall market is changing into a test as fundamental authority is winding up more essential, even at a short notification. Industry 4.0 offers start to finish straightforwardness logically, permitting the early check of framework decisions in the region of building and what's more versatile responses to the interference and overall improvement over most of the affiliation's districts in the area of age[49].
4. Resource productivity and efficiency: Huge numbers of the vital objectives for mechanical assembling procedures can even now be connected to Industry 4.0: as it conveys the most noteworthy conceivable yield of items from the given volume of assets and utilizing the least conceivable measure of assets to convey a specific yield (asset effectiveness). CPS brought about assembling forms being enhanced on a case-by-case premise over the whole esteem arrange. In addition, rather than stopping the creation, frameworks are ceaselessly improved amid the generation procedure as far as their asset and vitality utilization or decrease in their emanations[50].
5. Creating value opportunities through new services: Industry 4.0 gives an assortment of chances by making regard and new degrees of business, for example, through downstream organizations. Splendid estimations are accepted to be associated with the broad measures of contrasting data (colossal data) which are recorded by sharp things as they give creative organizations. There are important entryways for SMEs and new organizations to make business-to-business organizations for Industry 4.0[19].
6. Responding to demographic change in the workplace: Concerning work, affiliation and skill progression exercises, instinctive collaboration among individuals and mechanical systems will prepare for associations with new methodologies for making measurement change favorable for them. In the situation of the insufficiency of capable work and the creating grouped assortment of the labor force (similar to age, sexual orientation and social establishment), Industry 4.0 will allow unique and versatile calling ways as they will empower people to keep working and remain gainful for longer time spans[51].
7. work-life balance: Versatile work affiliation models of lots of associations that use CPS shows that they are in a circumstance to meet the creating solicitations of agents with a particular ultimate objective to strike a predominant concordance between their work and individual lives and moreover between personal development and

continued with capable progression. Splendid assist structures with willing prepare for new and better open entryways so work can be formed in a manner that passes on a predominant norm of versatility to meet the affiliation's necessities and the singular solicitations of agents. Exactly when the degree of the labor force lessens, it gives CPS associations a sensible favored angle similarly as enlisting the best agents[52].

8. A high wage economy that is still competitive: The twofold method of Industry 4.0 has empowered Germany to develop its circumstance as the primary supplier while transforming into the principal market for Industry 4.0 plans. Industry 4.0 can't in any case address the arranged or IT-related test to the critical undertakings. The powerful development is also expected that would have wide legitimate consequences, as it allows an opportunity to develop new associations and corporate models, hence uplifting bigger measures of delegate responsibility.

Technical Benefits

1. Towards responsiveness or agility

The planned assembling framework ought to react rapidly to the varieties in the framework, climate or change in the client requests and other economic situations [19].A deftness venture objective is to convey redone items and store network arrangements[46].

2. From automation to autonomous

In an intellectual plant, each machine and its cycle are furnished with intellectual capacities like human practices, which permit industrial facility conditions to react deftly and independently against the changes[53].

3. From several literature reviews it has been shown that Industry 4.0 enabling technologies, mostly the industrial IOT and clouds represent over 80% usage, particularly for security and safety management through the application of smart devices, advanced monitoring systems and elaboration of digital information. The Industry 4.0 implementation can be very helpful in warehouses and logistics where the issues which are related to safety of products, storage places, transportation, environment and operators can be efficiently managed through the use of RFID(Radio frequency identification)-IOT Technology[54].

VI.RESPONDENTS PROFILE AND RESPONSES RECEIVED

The questionnaire survey was submitted to 75 people, but we received 51 responses in total. Out of the total responses, 22 responses were received through Google form and the rest 29 responses were received through mutual communication.

Figure 1. Awareness of Industry 4.0 among respondents

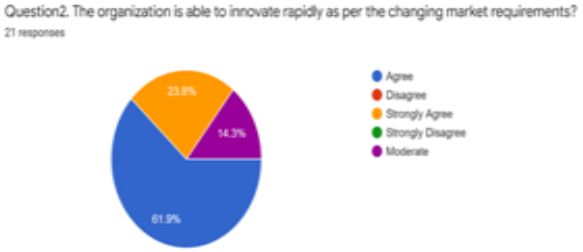

Figure 2. Summary of organization to innovate as per new market requirements

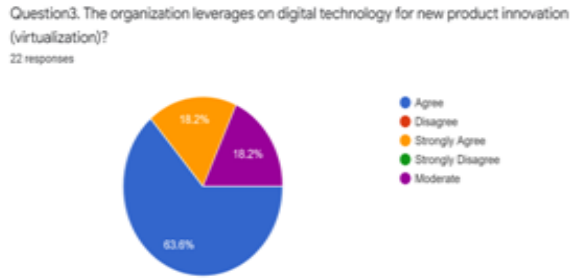

Figure3. Organization initiation to adopt virtualization

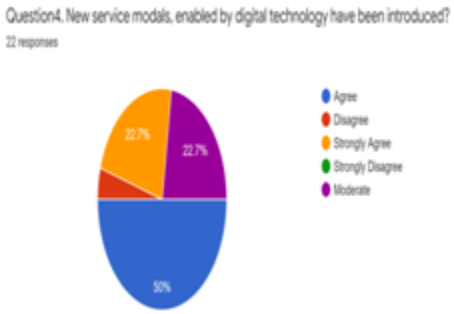

Figure 4. Awareness of Virtual Reality

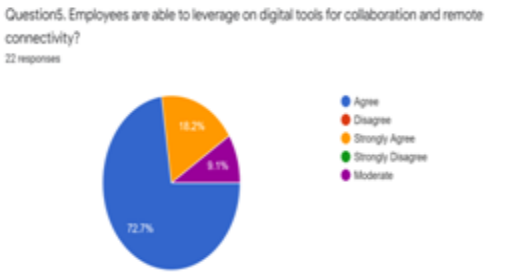

Figure 5. Employee collaboration and connectivity profile

Figure 6. Awareness of knowledge and skill enhancement tools

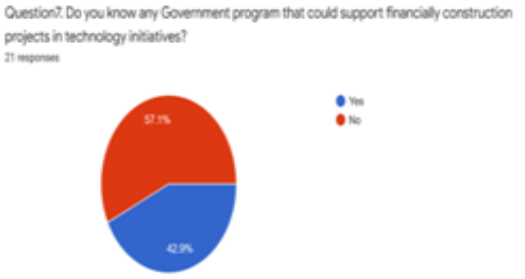

Figure 7. Govt. Program profile for Industry 4.0

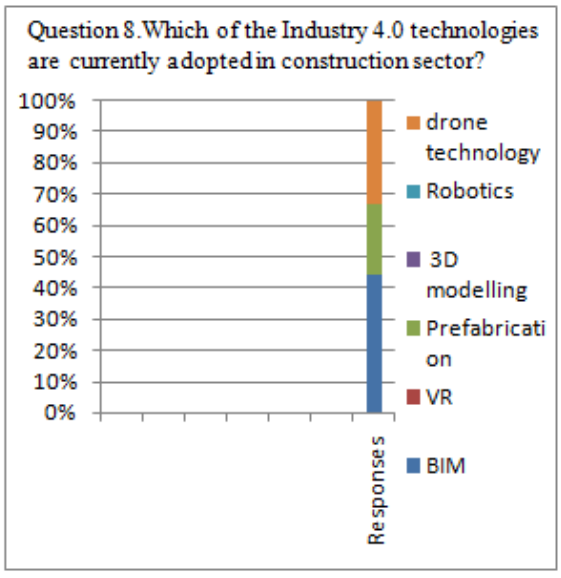

Figure 8. Current Construction 4.0 technology profile

VII. CONCLUSION

The expression "Industry 4.0" is currently a burgeoning term which is referred as a way of increasing automation of industrial processes and the connectivity between physical and virtual world. This paradigm of thoughts is accepted and adopted as a strategy for efficient and flexible production and development. The construction sector is immensely involved and is showing its firm stance to deploy this concept as its implementation is bringing together significant frontier technologies in communications, materials, logistics, energy, sustainability, as well as information management and facilities management. This fourth industrial revolution (4.0) is driven by the development of digital actual frameworks (CPS), IOT, IOS, process automation and system integration which helps us to merge the real and the virtual world to have a real time data exchange between actors and objects along the entire value chain. Basically, this radical transformation is a heap of innovations having huge potential to improve the communications and productivity by creating digital and flexible value chains. The main objective behind its implementation is to digitize and develop the intelligent, integrated, and fully autonomous factories called Smart or Dark factories. The smart products thus produced by these factories can provide new plans of action, new services and solutions to the customer and feedback for the development of new products.

As per the dynamic nature of construction projects, the implementation of this novel term suffers additional burdens with firms being more dependent on each other up and down the value chain than within other sectors like manufacturing and thus Industry 4.0 can't work for any one firm unless all firms fall in line behind digitization. Among several studies, the one as for example UK based construction company case study shared a view representing a significant new opportunity of Virtual Reality (VR) adoption, Building Information Modeling (BIM) and Digital Twin of construction and their application for active interaction through VR and simulation of activity prior to onsite construction. But the methods of powerfully executing the Industry 4.0 in construction projects are still a subject of exploration. This digital idea has an exceptionally mind-boggling innovation design of assembling frameworks which is one of the

fundamental worries in this new era. That is why there is a dire need to explore the enablers and barriers while its implementation in construction sectors. Clearly it can be put forward that without stringent monitoring its deployment in construction projects will not give fruitful results. Thus, for successful implementation of Industry 4.0 the constraints must be identified, analyzed and evaluated and also the firms and interoperable technologies needs to be integrated, so that a proper and perfect framework can be formed.

REFERENCES

[1] Gajdzik, B., Grabowska, S., & Saniuk, S. (2021). A theoretical framework for industry 4.0 and its implementation with selected practical schedules. *Energies*, *14*(4), 940.

[2] Kagermann, H., Wahlster, W., & Helbig, J. (2013). Acatech–National Academy of Science and Engineering. *Recommendations for implementing the strategic initiative INDUSTRIE, 4*.

[3] Oztemel, E., & Gursev, S. (2020). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, *31*(1), 127-182.

[4] Stock, T., Obenaus, M., Kunz, S., & Kohl, H. (2018). Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential. *Process Safety and Environmental Protection*, *118*, 254-267.

[5] RÜBMANN, M. (2015). Future of Productivity and Growth in Manufacturing. *Boston Consulting*, *n*.

[6] Birkel, H. S., Veile, J. W., Müller, J. M., Hartmann, E., & Voigt, K. I. (2019). Development of a risk framework for Industry 4.0 in the context of sustainability for established manufacturers. *Sustainability*, *11*(2), 384.

[7] Sony, M. (2020). Pros and cons of implementing Industry 4.0 for the organizations: a review and synthesis of evidence. *Production & Manufacturing Research*, *8*(1), 244-272.

[8] Davies, R., Coole, T., & Smith, A. (2017). Review of socio-technical considerations to ensure successful implementation of Industry 4.0. *Procedia Manufacturing*, *11*, 1288-1295.

[9] Alcácer, V., & Cruz-Machado, V. (2019). Scanning the industry 4.0: A literature review on technologies for manufacturing systems. *Engineering science and technology, an international journal*, *22*(3), 899-919.

[10] Pollak, A., Hilarowicz, A., Walczak, M., & Gąsiorek, D. (2020). A Framework of Action for Implementation of Industry 4.0. an Empirically Based Research. *Sustainability*, *12*(14), 5789.

[11] Müller, J. M., & Voigt, K. I. (2018). Sustainable industrial value creation in SMEs: A comparison between industry 4.0 and made in China 2025. *International Journal of Precision Engineering and Manufacturing-Green Technology*, *5*(5), 659-670.

[12] Cruzara, G., Takahashi, A. R. W., Sandri, E. C., &Cherobim, A. P. M. (2020). The impact of digital transformation and industry 4.0 on the aspects of value: Evidence from a meta-synthesis. *Contextus: Revista Contemporânea de economia e gestão*, *18*, 92-106.

[13] Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, *132*, 2-17..

[14] Lewin, H. A., Richards, S., Aiden, E. L., Allende, M. L., Archibald, J. M., Bálint, M., ... & Zhang, G. (2022). The earth BioGenome project 2020: Starting the clock. *Proceedings of the National Academy of Sciences*, *119*(4).

[15] Atashgar, K., & Zargarabadi, O. A. (2017). Monitoring multivariate profile data in plastic parts manufacturing industries: An intelligently data processing. *Journal of Industrial Information Integration*, *8*, 38-48.

[16] Vuksanović Herceg, I., Kuč, V., Mijušković, V. M., & Herceg, T. (2020). Challenges and driving forces for industry 4.0 implementation. *Sustainability*, *12*(10), 4208.

[17] Androniceanu, A. (2017). Hospital management based on the relationship between doctors and patients. *Revista» Administratie si Management Public «(RAMP)*, (29), 41-53.

[18] Aripin, I. D. M., Zawawi, E. M. A., & Ismail, Z. (2019). Factors influencing the implementation of technologies behind industry 4.0 in the Malaysian construction industry. In *Matec Web*

of Conferences (Vol. 266, p. 01006). EDP Sciences.

[19] Rejikumar, G., Arunprasad, P., Persis, J., & Sreeraj, K. M. (2019). Industry 4.0: key findings and analysis from the literature arena. *Benchmarking: An International Journal*.

[20] Acemoglu, D., & Autor, D. (2011). Skills, tasks and technologies: Implications for employment and earnings. In *Handbook of labor economics* (Vol. 4, pp. 1043-1171). Elsevier.

[21] Beata, Ś. (2018). Industry 4.0-Are we ready. *Revista Polaca de estudios de dirección*, *17*(1).

[22] Brettel, M., Friederichsen, N., Keller, M., & Rosenberg, M. (2017). How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective. *FormaMente*, *12*.

[23] Reams, B. D. (1986). *University-industry research partnerships*. Quorum.

[24] Andriushchenko, K., Rudyk, V., Riabchenko, O., Kachynska, M., Marynenko, N., Shergina, L., ... & Kuchai, O. (2019). Processes of managing information infrastructure of a digital enterprise in the framework of the Industry 4.0 concept. *Восточно-Европейский журнал передовых технологий*, (1 (3)), 60-72.

[25] Erol, S.; Jäger, A.; Hold, P.; Ott, K.; Sihn, W. Tangible Industry 4 . 0 : A Scenario-Based Approach to Learning for the Future of Production. *Procedia CIRP***2016**, *54*, 13–18. https://doi.org/10.1016/j.procir.2016.03.162.

[26] Buhr, D. (2017). Social Innovation Policy for Industry 4. 0. Publisher: Division for Social and Economic Policies.

[27] Kang, H. S., Lee, J. Y., Choi, S., Kim, H., Park, J. H., Son, J. Y., ... & Noh, S. D. (2016). Smart manufacturing: Past research, present findings, and future directions. *International journal of precision engineering and manufacturing-green technology*, *3*(1), 111-128.

[28] Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of production economics*, *204*, 383-394.

[29] Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. Intelligent manufacturing in the context of industry 4.0: a review, Engineering 3 (5)(2017) 616–630.

[30] Hossain, M. A., & Nadeem, A. (2019, April). Towards digitizing the construction industry: State of the art of construction 4.0. In *Proceedings of the ISEC* (Vol. 10).

[31] Lucas, R. E. (2002). The industrial revolution: Past and future. *Lectures on economic growth*, 109-188.

[32] Rauch, E. (2020, June). Industry 4.0+: The next level of intelligent and self-optimizing factories. In *Design, Simulation, Manufacturing: The Innovation Exchange* (pp. 176-186). Springer, Cham.

[33] Mohajan, H. (2019). The first industrial revolution: Creation of a new global human era.

[34] Roberts, B. H. (2015). The third industrial revolution: Implications for planning cities and regions. *Work. Pap. Urban Front*, *1*(1).

[35] Bartodziej, C. J. (2017). The concept industry 4.0. In *The concept industry 4.0* (pp. 27-50). Springer Gabler, Wiesbaden.

[36] You, Z., & Feng, L. (2020). Integration of industry 4.0 related technologies in construction industry: A framework of cyber-physical system. *IEEE Access*, *8*, 122908-122922.

[37] Kozlovska, M., Klosova, D., & Strukova, Z. (2021). Impact of industry 4.0 platform on the formation of construction 4.0 concept: A literature review. *Sustainability*, *13*(5), 2683.

[38] Newman, C., Edwards, D., Martek, I., Lai, J., Thwala, W. D., & Rillie, I. (2020). Industry 4.0 deployment in the construction industry: a bibliometric literature review and UK-based case study. *Smart and Sustainable Built Environment*.

[39] Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing letters*, *3*, 18-23.

[40] Schmidt, R., Möhring, M., Härting, R. C., Reichstein, C., Neumaier, P., & Jozinović, P. (2015, June). Industry 4.0-potentials for creating smart products: empirical research results. In *International Conference on Business Information Systems* (pp. 16-27). Springer, Cham.

[41] Santos, K., Loures, E., Piechnicki, F., & Canciglieri, O. (2017). Opportunities assessment

of product development process in Industry 4.0. *Procedia manufacturing*, *11*, 1358-1365.

[42] Berger, R. (2015). The digital transformation of industry. *The study commissioned by the Federation of German Industries (BDI), Munich (www. rolandberger. com/publications/ publication_pdf/roland_berger_ digital_ transformation_of _industry_20150315. pdf)*.

[43] Młody, M. (2018). Personalizacja produktów a Przemysł 4.0—ocena słuszności implementacji nowoczesnych technologii w przemyśle produkcyjnym z perspektywy konsumentów. *Ekonomika i Organizacja Przedsiębiorstw*, 62-72.

[44] Aguilera, D., & Ortiz-Revilla, J. (2021). STEM vs. STEAM education and student creativity: A systematic literature review. *Education Sciences*, *11*(7), 331.

[45] Dohale, V., & Kumar, S. (2018). A review of literature on Industry 4.0. In *National Convention of IIIE and International Conference*.

[46] Selak, L., Butala, P., & Sluga, A. (2014). Condition monitoring and fault diagnostics for hydropower plants. *Computers in Industry*, *65*(6), 924-936.

[47] Faller, C., & Feldmüller, D. (2015). Industry 4.0 learning factory for regional SMEs. *Procedia Cirp*, *32*, 88-91.

[48] Götz, M., & Jankowska, B. (2017). Clusters and Industry 4.0–do they fit together?. *European Planning Studies*, *25*(9), 1633-1653.

[49] Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic approach for human resource management in Industry 4.0. *Procedia Cirp*, *54*, 1-6.

[50] Herter, J., & Ovtcharova, J. (2016). A model based visualization framework for cross discipline collaboration in industry 4.0 scenarios. *Procedia CIRP*, *57*, 398-403.

[51] Branger, J., & Pang, Z. (2015). From automated home to sustainable, healthy and manufacturing home: a new story enabled by the Internet-of-Things and Industry 4.0. *Journal of Management Analytics*, *2*(4), 314-332.

[52] Gölzer, P., & Fritzsche, A. (2017). Data-driven operations management: organisational implications of the digital transformation in industrial practice. *Production Planning & Control*, *28*(16), 1332-1343.

[53] Petrelli, D. (2017). Industry 4.0: Is it time for interaction design craftsmanship?. *The Design Journal*, *20*(sup1), S2735-S2745.

[54] Forcina, A., & Falcone, D. (2021). The role of Industry 4.0 enabling technologies for safety management: A systematic literature review. *Procedia computer science*, *180*, 436-445.

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