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Drivers of Industry 4.0 Implementation in the Construction Industry

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Abstract
The construction industry significantly influences the economy and development of a country. However, the construction industry is conservative and cannot make quick changes. The main reasons are the uncertainty and complexity of the construction projects. Compared to the speed of development of the manufacturing industry, the construction industry is relatively slow to change the usual practice and develop technologically. Therefore, the construction industry must review and implement modern technologies that make the construction processes faster and cheaper. The fourth Industrial Revolution may become a decisive factor and a driver for its development. This work analyzed the importance of Industry 4.0 for the construction industry and the main driving factors for its implementation. Its driving factors are technological, economic, social, and environmental. The state of the construction industry in Kazakhstan was studied using the example of a leading construction company. The results yield that private construction companies should investigate and implement more digital technologies. The limitation of the part about Kazakhstan is the lack of available information due to low transparency. Thus, more companies with various statuses and from different locations should be evaluated for a more rigorous analysis.

Keywords
BIM, Construction Industry, Cyber-physical systems, Industry Revolution 4.0, IoT

1. Introduction

The construction industry significantly influences the economy and a country's development. The World Bank (2020) reports that the construction industry had approximately 6% and 7% of the world and Kazakhstan's GDP in 2019. The construction sector involves many other subsectors, such as producing and manufacturing construction equipment and creating many workplaces for unskilled workers (Berk & Biçen, 2017). It consumes approximately half of steel manufacturing and creates 18 million workplaces in Europe (Craveiro et al., 2019). According to Maskuriy et al. (2019), the world's urban population increases by 200,000 people every day. The demand for the construction industry is increasing with the rise of the urban population and the need for affordable housing, roads, and infrastructure. For a long time, construction processes have used inadequate and unsafe technologies. The industry implements new technologies and slowly transforms (Wesam et al., 2020). However, the construction industry must review and implement modern technologies making the process faster and cheaper.

After the first three industrial revolutions, which accelerated manufacturing industries with steam engines, mechanical automatization, electronics, and the Internet, the fourth revolution brought the digital transformation. It includes modern technologies such as Building Information Modelling (BIM), Internet of Things (IoT), additive manufacturing, 3D printing, drones, sensors, scanners, collecting of all data and their analysis, etc. (Woodhead et al., 2018). Industry Revolution 4.0 (Industry 4.0) or Construction 4.0 offers a sustainable complex manufacturing system of high-level technologies integrated into design, manufacturing, and construction processes (Wesam et al., 2018). With Industry 4.0, construction companies could effectively plan and schedule their work processes, tackling project overruns and delays (Horváth & Szabó, 2019). As a result, both the industry and the clients can benefit from it.

However, the construction industry is conservative and slow to change due to the complexity and uncertainty of the projects. Most construction projects include many stakeholders with their interests, and it is not very easy to transform all of them. Fragmentation of processes, employee turnover, and uniqueness of all projects are the challenges (Oesterreich & Teuteberg, 2016). All these factors decelerate the transformation process.

The driver factors of Construction 4.0 could urge the industry to implement digital technologies faster despite obstacles. These factors could include technological directions and economic, social, and environmental factors. Studying these factors is essential, as it could investigate the construction industry and its transformation process. Found data may help predict the future of the industry. This paper aims to find and clarify the main driving factors of the Industry 4.0 implementation in the construction industry. The objectives of the study are:

1. To describe the importance of Industry 4.0 in the perspective of the Construction Industry,
2. To identify the main economic, technological, social, and environmental factors which promote the development of Industry 4.0,
3. To study Kazakhstan's progress in the construction industry in Industry 4.0.

Many research papers and reviews limit their area to technological and economic factors. However, the implementation process is more complicated, so social and environmental factors could also be necessary. This paper investigates the social and environmental possible factors and determines the links between them. It also includes a study of the development of the construction industry in Kazakhstan. The study of the state of the construction industry in Kazakhstan was reviewed for the first time in this paper.

2. Methods

The methodology includes the collection and analysis of research papers. Keywords for the search were industry revolution 4.0, construction 4.0, digital construction, and modern construction. Sources that include these phrases were selected from the Scopus and Elsevier databases. After a quick scan of numerous papers, the most relevant paperswere selected and analyzed. In this paper, the state and importance of Industry 4.0 are defined in terms of the construction industry. Its main driving factors were technological, economic, social, and environmental categories. The construction industry's status quo was analyzed, and the implementation status of modern technologies was evaluated.

In the literature, there is a lack of information about the construction industry in Kazakhstan. For identifying the status of Industry 4.0 and the overall construction industry in the country, mainly information from the media was used. One of the biggest construction companies was interviewed to examine the quality of the country's construction sector. The data analysis and the interview results were included in the article.

3. Results

3. 1 Drivers of Industry 4.0

Recent research on the development of Industry 4.0 in the construction industry found that the most critical development drivers are economic, technological, and social factors (Wesam et al., 2020). The study authors examined the reviewed literature and conducted a survey. The data obtained were analyzed using the Six Sigma Quality Initiative and DMAIC methods. The three factors mentioned above were the most relevant among the seven factors, including political, environmental, legal, and security (Fig.1). For this research, economic, technological, and social factors were chosen as the most critical factors. Environmental factors were also analyzed due to their increasing importance to global warming. The driving factors by categories have been outlined in Table 1 and explained.

Economic Factors

***Savings by optimization*.** According to the World Economic Forum (2018), only 1% of construction optimization can save $100 billion worldwide. With the development of the industrial revolution, technology could save time and materials and minimize industrial risks.

Reduce construction time. The presence of a unified system, computing power, and the ability to quickly share information could make it possible to work efficiently and without significant losses. New supply chains for materials and equipment could reduce time, and work could be finished on schedule (Craveiro et al., 2019). Sensors, cameras, and drones could follow the workflow, and necessary changes or errors could be found and fixed in a short time (Stergiou et al., 2018). Reduced construction time could decrease the cost of delays and wages.

Increasing construction speed. The development of prefabrication and/or additive manufacturing technologies could make massive production of the main parts. It could increase the speed of construction compared to conventional methods (Craveiro, 2019). Moreover, mass production decreases the cost of construction.

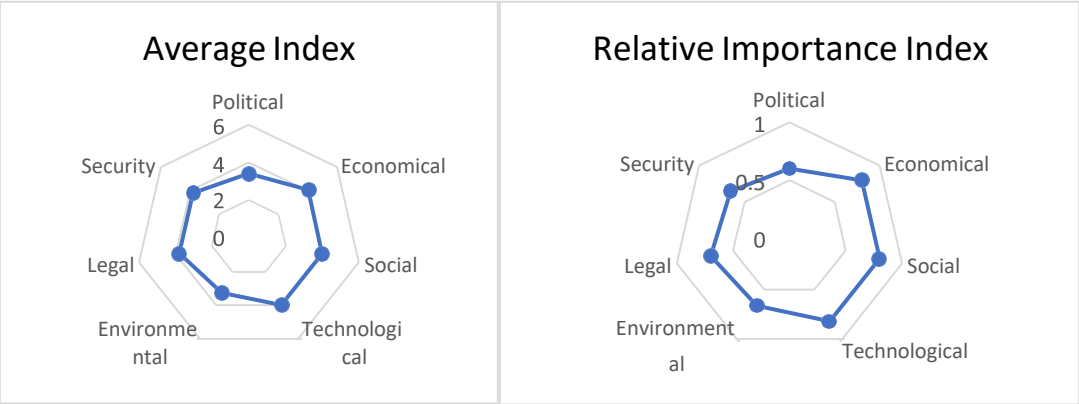

Fig. 1. Average and relative importance indexes of the studied factors (Wesam et al. 2020)

Table 1. Driving Factors by categories

1. Economic	2. Technological	3. Social	4. Environmental
5. Savings by optimization	6. Improved quality	7. Communication between stakeholders	8. Reduction of carbon dioxide emission
9. Reduce construction time	10. Monitoring	11. Digitalization	12. Reduction of waste generation
13. Increasing the construction speed	14. Quality	15. Virtual opportunities	16.
17. Automatization	18.	19. Improve the industry image	20.

Automation. In the future, autonomous machines and robots could be used by necessity. Their advantage over people is that they can work effectively for a long time, are connected to a single base, and have a machine learning system (Ben-Ari & Mondada, 2017). In the long term, they could save money on people's salaries, increase the efficiency and speed of work, and minimize the human error factor. On a global scale, implementing demonstrated automation technologies in industries could affect half of the world's economy, or 1.2 billion employees and USD 14.6 trillion in wages. The Industrial Revolution 4.0 could affect the world more than any other revolution.

Technological factors

Improved quality. The development of modern technology could improve the quality of construction and minimize possible defects. A single self-training system on a database could determine the most effective construction methods for each case (Wei & Li, 2011). It could be possible to monitor the quality of work during and after construction. The development and implementation of additive manufacturing and 3D printing could increase the construction works. The buildings (or their parts) made by machines could make mistakes with a lower probability than humans.

Monitoring. The use of sensors that determine the work's condition could reduce the risk of shoddy quality work. Sensors for concrete could determine the hardening and curing processes. After a long time, it could be possible to monitor the concrete state and, if necessary, carry out repair work on time (Song, Gu & Mo, 2008). The same sensors can be designed for each particular type of job. Drones with laser scanners could determine welding or masonry quality (Goessens, Mueller & Latteur, 2018). With these technologies, the quality of the work performed could be increased.

Safety. The construction industry is one of the most dangerous workplaces. Because of short-time activities and the work industry, tracking the workers' safety is challenging. The sensors and cameras connected to the intelligent database could alarm the possible hazard, and the risks could be minimized efficiently (Howard et al., 2018).

Social factors

Communication between stakeholders. For completing one project, the construction industry attracts many stakeholders, such as owners, architects, contractors for various works, suppliers of materials and equipment, etc. Communication and interaction between all actors considerably influence the time and quality of work (McCaffer, 2014).

Digitalization. Innovative technologies could create new types of interaction among all actors. Outdated models of contracts and businesses have some difficulties with bureaucratic processes (Wesam et al., 2020). The digitalization of the industry could offer new ways to interact with partners and customers.

Virtual opportunities. By applying simulation technologies like augmented reality, virtual reality, and mixed reality combined with mobile devices or wearable computing, construction companies can provide project owners with more significant insight into the building's details and design before being built (Dallasega, 2018). Therefore, customers can be involved in the planning process to customize the building better.

Improved image of the industry. The construction sector is notorious for its difficult working conditions and lack of digitization. As a result, it has a negative employer reputation and often fails to hire qualified employees (Oesterreich, 2016). The tech transformation could improve the image of the whole sector.

Environmental Factors

The building and construction sector is responsible for 38% of all energy-related carbon dioxide emissions caused by energy consumption and high waste levels during its construction processes (UN, 2019). Several approaches have been proposed for construction waste minimization to handle these environmental problems, reduce project emissions through strategic project management, or use BIM to create design alternatives.

Reduction of carbon dioxide emission. According to UN statistics, 11% of global CO_2 emissions come from the construction industry. The central part of which is the production of construction materials such as cement, glass, and steel (UN, 2019). In Industry 4.0, research and experiments with new materials will produce fewer emissions. It is critical to aggressively explore ways to reduce CO_2 emissions and promote energy conservation. To reduce the weight of concrete buildings, McCaffer (2014) devised a method for printing concrete with differing densities by combining concrete with aluminum powder and lime, which react to create hydrogen gas bubbles and form a foaming structure. On the other hand, Oh et al. (2015) used a robot and a programmed syringe dispenser to inject the aluminum solution into the precise position of a white cement panel, resulting in customized patterns of holes. Herrmann and Sobek (2017) have used graded spraying techniques to create structural components that were mass optimized. These innovations can decrease the use of cement and, as a result, CO_2 emissions.

Reduction of waste generation. A resource-efficient construction sector with lightweight structural components will reduce waste generation, emissions, and global resource consumption. Furthermore, thin/light walls avoid overloading the building structure, reducing cement consumption, which is responsible for approximately 5 to 8% of CO_2 worldwide (Craveiro, 2019). The development and usage of more eco-friendly materials minimize waste production.

In Table 2, the influence of Industry 4.0 technologies has been conceptually mapped to the driving factor categories.

Table 2. Conceptual matrix of how driving factor categories affect Industry 4.0 technologies (H – high, M – medium, L – low)

21. Industry 4.0 Technologies	22. Economic	23. Technological	24. Social	25. Environmental
26. Additive Manufacturing/ 3D Printing	27. H	28. M	29. L	30. M
31. Artificial intelligence	32. M	33. H	34. L	35. L
36. Augmented reality / Virtual reality	37. M	38. H	39. H	40. L
41. Big Data Analytics	42. M	43. M	44. L	45. L
46. Building Information Modelling	47. H	48. H	49. H	50. H
51. Cloud computing technology	52. L	53. H	54. L	55. M
56. Cyber-physical systems	57. M	58. H	59. L	60. L
61. Drones / Unmanned Aerial Vehicles	62. M	63. M	64. M	65. M
66. GIS mapping	67. M	68. M	69. M	70. L
71. Internet of things (IoT)	72. H	73. H	74. M	75. M
76. Laboratory research	77. L	78. H	79. L	80. H
81. Laser scanning	82. M	83. H	84. L	85. M
86. Robotics and automation	87. H	88. H	89. M	90. M
91. Sensors / Semantic product memory	92. H	93. H	94. M	95. L

3.2. The status of Industry 4.0 technology in the Construction Industry in Kazakhstan

The construction sector in Kazakhstan remains one of the most critical sectors of the economy and one of the most attractive investment areas. This sector accounts for up to 7% of Kazakhstan's GDP; the construction sector provides

about 700,000 jobs. The stabilizing macroeconomic situation with moderate growth in real GDP will affect the construction sector in Kazakhstan. According to the World Bank (2020), the share of operating legal entities in the construction industry is slightly more than 13% of the total number of organizations conducted in the republic. The increase in operating legal entities from 2012 to 2016 amounted to approximately 34%. The volume of completed construction work in nominal terms demonstrates positive dynamics.

Construction in Kazakhstan is subdivided into constructing buildings and structures, civil engineering, and specialized construction work. They are carried out as part of the general construction process, with further division by area. The specific share of completed construction work falls to the private sector in ownership forms. 66.2% of all construction works were done by private companies, 33.2% by foreign companies, and only 0.5% by national companies in 2016. The high share of foreign companies could be explained by EXPO 2017 when they were involved as contractors. Usually, the percentage of foreign companies fluctuates at 20-25%.

The most prominent specific shares are concentrated in the construction of non-residential buildings (up to 23%), the construction of roads and highways (up to 19%), and the construction of residential buildings (up to 10%) (World Bank, 2020).

3.3. The Industry 4.0 in Kazakhstan

Since 2017, Kazakhstan's Government has begun preparing and developing a plan to introduce state-owned enterprises' latest technology. According to the Kazakhstan Institute for Industrialization Development, Industry 4.0 can solve the country's following problems: 1. Systematic staff shortage 2. Labor in hazardous areas 3. The insufficient domestic market for mass production, and 4. High transport costs and being landlocked (Informburo, 2017). Turkyilmaz (2020) found that for SMEs in Kazakhstan, Industry 4.0 could improve companies' economic performance by reducing costs and increasing labor productivity. Moreover, implementing new technologies could help companies react quickly to market changes.

However, at the beginning of 2018, according to the Ministry of Investment and Development, most Kazakhstani companies were not ready for a full-fledged transition to Industry 4.0. According to the data presented at the next meeting of the Government, 84% of enterprises in the processing industry and more than 56% in the mining industry correspond only to Industry 2.0 - this is a semi-automated production or a stage of transition to automated production (Informburo, 2017). Based on their analysis, the main constraints for the implementation of Industry 4.0 are:

- Insufficient business understanding of the economic benefits of digitalization
- Poor development of domestic development and competencies in automation and digitalization
- Lack of qualified personnel
- Limited Financial Resources
- Infrastructural Constraints

Except for the given reasons, Turkyilmaz (2020) added the absence of a proper strategy and the shortage of financial resources as the SMEs' additional weaknesses in Kazakhstan.

Under government programs, pilot innovation projects occur mainly in mining and oil and gas enterprises. These companies export to the international market and need to be competitive. For example, ERG's Sokolovsko-Sarbaisky Mining and Concentrating Production Association has launched the Smart Quarry and Smart Factory projects (Informburo, 2017). In 2016, Kazatomprom-SaUran launched the Digital Mine pilot project. Another miningcompany, Kazzinc, implements seven digitalization projects at once (Informburo, 2017). In addition, by 2019, 14 projects were implemented for 7.5 billion tenges and planned to introduce digital solutions for another 90 enterprisesby 2022.

Construction companies are not yet on the list of innovative ones. The reason may be the problems mentioned above in the construction industry and that most of the state's construction sector is private. For this reason, construction companies have to take matters into their own hands. However, advanced digital enterprises in the country and the state's support can attract more investment, helping develop the construction sector.

4. Discussions

The construction industry's future is highly dependent on the direction and speed of the development of new technologies. Industry 4.0 technology will cover all construction stages, including planning, design, construction, and management (Wesam et al., 2020). Due to automation, each separate phase of the construction process could be cheaper and more qualified.

BIM technology allows planning construction in several directions in one system, including design, scheduling, progress, and the project's economic components. With augmented reality technology, BIM could see how construction could solve possible problems and inconsistencies even in the planning stage (Hu & Zhang, 2011). BIM could analyze the previous data with machine learning and neural networks and offer optimal solutions and construction plans (Davtalab, Kazemian & Khoshnevis 2018).

Cloud computing technologies could quickly analyze data from BIM and various sensors and share the information with everyone in real-time (Birje et al., 2017). The data can be accessed on the construction company servers and the tablets and phones of workers and engineers (Xu et al., 2015). This technology could improve information delivery and communication speed among different stakeholders.

Every digital equipment on the construction site could access the Internet and send/update new information to the server. This technology is known as the Internet of Things (IoT) (Woodhead, 2018). The data obtained from BIM, cloud computing, and IoT could be extensive, and advanced big data technology could be needed for their analysis. The developed cybersecurity technology could also be necessary for this data's security (Alavi & Gandomi,2017). The blockchain and/or other advanced technologies for data encryption could be used.

With the development of the technologies mentioned above, the management of necessary materials and logistics could become more efficient. Logistics managers could see the number of materials in the warehouse; when they run out, they could order the amount required in advance without mistakes and monitor the delivery process (Craveiro et al., 2019). This mode could save time and reduce the risk of delays.

Unmanned aerial vehicles (UAVs), or drones, can survey the construction site and track the construction process. With the help of cameras or laser sensors, drones can obtain data about an area's landscape or the 3D dimensions of particular objects (Caterpillar, 2017). This data could be processed and be available to be used for design. Drones can also track progress and safety at a construction site (Howard et al., 2018).

Developed laboratories and the study of various building materials could discover or create new durable and inexpensive building materials that could also change the vision of the construction industry. With the development of new materials, the problems with concrete (low tensile strength) or steel (corrosion) could finally be solved (Das & Mitra, 2014). 3D printing technologies, autonomous machines, and robots could be massively used in constructionin the distant future. These vehicles could transmit all data in real-time, analyze it continuously, learn, and develop themselves (Oh et al., 2015).

The development of all possible technologies could improve the speed and quality of construction processes. These technologies could be connected to one system, and all data could be analyzed and show progress in real-time. They could improve the construction management supply chain and make construction cheaper; new technologies could minimize the number of mistakes and make the construction more qualified and environmentally sustainable.

To study the development of new technologies in the construction industry in Kazakhstan, as part of the research, an interview was conducted with representatives of the country's largest construction company. The company works on the development and implementation of new technologies in construction. During the consultation, the application of modern technology in Kazakhstan was discussed.

Modern technologies are used in the planning and construction stages of the company. Standard software for BIM is used in the early planning stages, like *Autodesk Revit*. Furthermore, Russian developers' software parametric is also used to compile an automatic sketch model. The *BIM Check* software checks the plan for possible errors, such as inaccuracies in measurements or impossible pipe crossings.

Drones equipped with modern cameras and laser scanners survey the territory and construction sites. Drones explore the region, and particular software can automatically draw a 3D landscape of the place. Later, drones are also used to check the facade and compare it with the design. Drones can additionally calculate massive volumes of materials such as sand or cement. They are fast and efficient and help to get the job done in a short time.

Sensors are also used during construction. Leakage sensors are installed at the lower levels, and if water starts to leak, inform workers about it. The leak can be repaired very quickly and without damage to the project. Concrete sensors help monitor the quality of pouring, hardening, and curing. If necessary, concrete is repoured, and the risk of poor-quality pouring is minimal.

The cameras are placed along the perimeter of the construction site and connected to the main servers. Here, the recordings from the cameras are analyzed, and if unusual actions are detected, it informs the security about what is happening. These recordings help to monitor site safety more efficiently.

The company is authorized to develop solutions to systematic problems. In Kazakhstan, construction regulations prohibit work at high wind speeds. Wind speed data are received from the *Kazhydromet*, which has meteorological stations outside the city. However, most construction work is done in the city, where the wind speed is less than

outside. Few portable meteorological stations have been developed to determine the construction site's wind speed to solve this problem. Now, using these stations allows builders to not delay work due to inaccurate data.

The company is now developing software to optimize project planning and new neuro links to draw the most efficient parking spaces within a specified zone. They have also been practicing trained neural networks to evaluate their property cost for a long time. The algorithm can determine the price change in the market in real-time and, depending on the given factors, the optimal price for the estate. 3D printing and autonomous work are still being tested in the company, but they will not be used in large quantities as in the whole world soon.

Technology development is generally comparable in Kazakhstan relative to the world's construction industry. However, the limitation of this research is that the leading companies' practice was studied. Many small construction companies still use outdated technologies. Broader research is needed to get a complete picture of the country's technology development status.

5. Conclusions

The construction industry needs the development and efficient implementation of new technologies. The current challenges facing the industry cannot be overcome without effective optimization. The development of Industry 4.0 could be a possible solution. With the evolution of numerous technologies, the construction process is already changing. BIM and gadgets such as drones and sensors are already widely used; other technologies like IoT or cloud computing are in the implementation stage. Future technologies, such as advanced materials or autonomous vehicles, are not considered due to the industry's possible high cost and conservatism. As part of the study, the importance of the industrial revolution for the future of the construction industry was studied, and the main driving factors of development were found. The economic, technological, social, and environmental driving factors were investigated and explained. The potential monetary benefits, high-tech quality of construction work, well-established communication, and environmental sustainability will promote Industry 4.0 in the construction industry.

The state of the construction industry in Kazakhstan was studied and analyzed. The data shows that private construction companies should investigate and implement more digital technologies. The limitation of the part about Kazakhstan is the lack of available information due to low transparency. All the information from the media could be biased. For the primary search, only one construction company employee was interviewed. More companies with various statuses and from different locations should be evaluated for a more precise analysis.

Acknowledgment

This research was supported by the Nazarbayev University Competitive Grants Program (Funder Project Reference: 021220FD2251, Project Financial System Code: SEDS2021022.

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