



Transformative Potential of Artificial Intelligence for Enhancing Efficiency, Labor Productivity and Quality in construction sector in Kazakhstan

**D.O. Bazarbayev^{1*} , D.K. Zhumadullaev² , L.I. Ramatullaeva² ,
S.S. Shukirova² , B.T. Uakhitova³ **

¹*L.N. Gumilyov Eurasian National University, Astana, Kazakhstan,*

²*M. Auezov South Kazakhstan University, Shymkent, Kazakhstan,*

³*K. Zhubanov Aktobe Regional University, Aktobe, Kazakhstan*

E mail: ¹bazarbayev_do_1@enu.kz, ²daulet4403@gmail.com, ²ramatullaeva_l@mail.ru, ²shukirova.symbat@gmail.com, ³buakhitova@zhubanov.edu.kz

Abstract. The construction industry is essential to Kazakhstan's socioeconomic development but faces low labor productivity, project delays, and inefficient supply chains. This review examines the potential of artificial intelligence to improve construction efficiency, labor productivity, and quality control, drawing on international literature and considering its relevance to Kazakhstan. A thematic literature synthesis organizes the discussion around these three areas. The reviewed applications include predictive analytics, scheduling optimization, robotics, building information modelling, and automated defect detection. The synthesis indicates that these technologies can support resource allocation, project coordination, productivity prediction, and more consistent inspection. However, their benefits depend on data quality, digital infrastructure, workforce capabilities, and organizational readiness. The contribution of the review is to connect reported applications with the conditions affecting their transfer to Kazakhstan's construction sector. The findings support context-specific pilot projects, workforce training, and coordinated development of digital capabilities. The proposed directions offer a basis for evaluating AI adoption in construction practice and for further research on implementation under local conditions.

Keywords: Artificial Intelligence, AI integration, construction, efficiency, Kazakhstan.

Introduction

Construction, as a significant industry, plays an important role in driving social and economic growth and long-term national development. The construction industry worldwide including Kazakhstan has been slow in adopting new methods, and technologies. This sluggishness in adopting digital technologies, and automation is a barrier to productivity improvements [1].

Worldwide it is observed that poor labor productivity throughout the building process is an evident concern, resulting in waste of personnel, material resources, and financial resources; similar concern is observed in Kazakhstan. The construction sector in Kazakhstan is now undergoing a significant transformation, reaching a critical juncture in terms of technical advancements. The government of the Republic of Kazakhstan has taken the initiatives of BIM adoption in 2016 under the umbrella of Technology of Information Modeling of Construction Facilities (TIMCF) The goal of this initiative was to implement the 'Concept' - a 'Roadmap for information modeling technology implementation when designing construction facilities (BIM-technology)' for the periods of 2018-2022. Despite this ambitious initiative, project stakeholders face number of technology and process-related risks and barriers in implementing BIM [2].

The demands for more efficient, cost-effective, and sustainable construction practices have never been sustainable in Kazakhstan. Because building operations contribute significantly to our society's economic well-being, it makes the most sense to implement appropriate construction wise operations in order to improve product performance in Kazakhstan. Construction projects in Kazakhstan face a number of difficulties [3]. In particular the construction sector is characterized by low technological advances, low productivity, minimum automation and computerization [3]. The integration of Lean Reduce operational interruptions 4.0 such as Lean manufacturing tools and digital technologies, can significantly reduce operational interruptions and improve labor productivity. Despite, these practices are not fully yet adopted in Kazakhstan's construction sector [4].

In addition to that, inadequate project planning and management can lead to delays and budget overruns; inefficiencies in the supply chain can disrupt material and equipment delivery. Addressing these complex concerns is critical for effective and long-term building in Kazakhstan. In today construction sector experiences rapid technological progress, a particular breakthrough emerges as possessing profound transformative potential: Artificial Intelligence (AI). The construction industry faces a multitude of challenges. There is a growing recognition of AI's potential to mitigate these challenges meaning that with the increased generation of data throughout the building lifecycle, as well as the introduction of other digital technologies, AI has the potential to utilize this data and use the capabilities of other technologies to enhance construction operations [5]. AI is a multidisciplinary field of computer science that encompasses several disciplines and enables robots to simulate human-like intellect, acquire knowledge, and make decisions. The potential exists for a fundamental transformation in the planning and management of construction projects. The process of using this potential in Kazakhstan is hindered by a substantially notable gap particularly the lack of local research on the integration of artificial intelligence in the construction sector. AI integration in construction is a global phenomenon; the extent of local research in Kazakhstan remains limited. While there is a rapid adoption of AI-driven solutions in global construction hubs, the application of such technologies in Kazakhstan's construction industry is limited due to the lack of resources and local research, and infrastructure.

Therefore, in the context of an industry characterized by a lack of adoption of AI, this paper aims to emphasize the importance of implementing AI-driven innovations in Kazakhstan's

construction sector by analyzing global trends, successful international case studies, and best practices in AI integration within the industry. The primary objective is to facilitate the widespread use of AI technology, improve building methodologies, and stimulate innovation, thus positioning Kazakhstan's construction sector on the forefront in technical advancement and global competitiveness. Guided by the aims and objectives of this paper, this study seeks to answer the following question:

What is the potential for AI technology application in Kazakhstan's construction industry based on international literature?

This article has several sections, including an introduction where the background and significance of the study are presented. The methodology section outlines the thematic literature review procedure. Findings summarize the impact of AI in relation to efficiency, labor and quality control, showcasing international case studies and practices. The discussion part extensively elaborates on the implications of findings to the unique challenges and opportunities within Kazakhstan's construction sector. The article provides future recommendations with a goal to stimulate AI innovation in Kazakhstan's construction sector.

The methodology

This study used a thematic literature synthesis as an approach to analyze and identify key trends in the application of artificial intelligence (AI) within the construction sector. We focused on three thematic areas that appeared in scientific literature: efficiency, labor productivity, and quality enhancement.

Connected papers was used as the main search tool to enter the field, which provided a visual network of publications based on bibliographic coupling and co-citation; relevant publications identified during the search were subsequently used as new seed papers. This process of search was repeated, progressively expanding the search through bibliographic coupling and co-citation links.

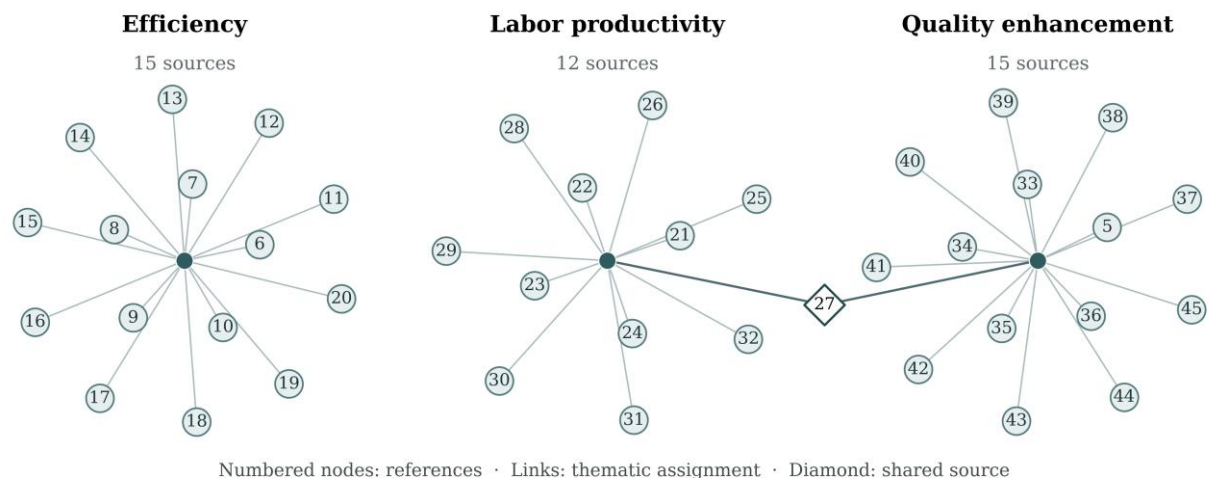


Figure 1. Thematic map of the 41 sources discussed in the three results subsections. Numbered nodes correspond to bibliography entries; links indicate assignment to a theme, not citation relationships. Source [27] contributes to two themes. Compiled by the authors.

This article is a thematic narrative review of AI and related digital technologies in construction. The analysis is organized around efficiency, labor productivity, and quality enhancement. Figure 1 and Table 1 map the 41 distinct sources cited in the three thematic results subsections preceding

Table 2; it does not represent a sample obtained through a reproducible systematic screening procedure. Each source is counted once within a subsection, and sources relevant to more than one subsection are counted in each corresponding row but only once in the overall total. Earlier publications are retained where they provide relevant technological or contextual background. Table 2 groups selected applications by technology, construction task, and potential implications for Kazakhstan. These implications are qualitative analytical proposals rather than locally measured effects. The synthesis does not pool effect sizes, and differences in study design, application context, and data availability limit direct comparisons between publications.

Table 1. Sources cited in the thematic results subsections

Theme	Number of cited sources	References
Efficiency	15	[6–20]
Labor Productivity	12	[21–32]
Quality Enhancement	15	[5, 27, 33–45]
Total distinct sources	41	[5–45]

Note: Counts cover the three thematic results subsections preceding Table 2. Reference [27] is cited in two subsections, so the row counts sum to 42 and the distinct-source total is 41. Citations appearing only in Table 2 or in the subsequent discussion are excluded.

Findings/Discussion

Efficiency

It is critical to recognize the difficulties that the building sector is facing today. The lack of digital skills and unwillingness to use innovative technologies have been linked to cost inefficiencies, project delays, and poor quality, productivity, and safety [6]. The introduction of AI-driven solutions has triggered a transformative revolution, resulting in significant improvements in processes, cost-efficiency, reduced production times, and enhanced safety measures while also aligning with sustainability goals [7–9]. Salih and El-Adaway [8] identified improved safety, increased productivity, informed decision-making, and enhanced monitoring and control as the affordances most consistently recognised both in their survey of 52 construction practitioners and the reviewed literature. The findings showed that the adoption of AI techniques and construction technologies could improve cost management by 64.66%, time-management performance by 70.18%, and quality management by 60.73%. Furthermore, the study found that productivity improvements affected project time and cost. In addition, monitoring, decision-making and improved safety influenced three targeted principal project objectives, including time, cost and quality.

The use of artificial intelligence (AI) tools in construction management has emerged as a critical driver for improving operational efficiency and overall project success. Process mining, an AI-enabled technique, has acquired attention for its ability to derive substantial insights into the complexities of building operations, as reported in many literature sources. Process mining, among other things, makes it easier to analyze essential operations, forecast deviations, identify hidden bottlenecks, and extract collaborative patterns. Such expertise is indisputably critical in assuring

the success of construction projects and directing the optimization of the construction execution process. This optimization comprises removing unnecessary stages, reducing rework and disputes, avoiding possible delays, and encouraging improved cooperation, which, in turn, allows decision-makers to act proactively [10–13].

Furthermore, optimization algorithms have shown to be effective tools for developing building plans that achieve the best balance of time, money, and quality [14–16]. Son and Khoi [14] extended this optimisation approach by additionally incorporating work continuity along with time, cost, and quality. AI-powered robots have shown tremendous potential in labor-intensive, repetitive construction jobs such as bricklaying, welding, and tiling [17]. These robots work continuously, without breaks, and with consistent quality, highlighting the enormous potential for improving efficiency, productivity, and, ultimately, profitability in the construction sector [18].

The handling of large volumes of data in the construction sector involves the use of advanced data analytics techniques, particularly with a focus on waste reduction. This need includes the combination of AI approaches with Building Information Modelling (BIM) to make it efficient to optimize numerous aspects such as design for material selection, offshore construction, reuse, recovery, deconstruction, and flexibility and waste-efficient procurement [19, 20].

Labor Productivity

Given the current challenges confronting the construction industry, such as labor shortages, the disruptive impact of the Covid-19 pandemic, and the imperative to meet the growing demand for sustainable infrastructure, the field's consensus emphasizes the importance of embracing digitization and augmenting technological capabilities [21, 22]. This overriding goal may be seen in numerous significant topics discussed in the review article.

The most prominent of them is the expanding investigation of machine learning as a transformational remedy to labor scarcity in the construction industry [23–26]. With the potential to significantly increase production and efficiency, machine learning offers the promise of optimizing resource allocation within construction projects, a capability that cannot be overstated. A parallel industrial effort is based on the purposeful deployment of optimization techniques to recalibrate and simplify building processes. This strategy execution guarantees that resources are used wisely, boosting the industry's productivity efforts [27].

Simultaneously, the construction industry is witnessing amazing advances in robots that can mitigate manual labor [22]. This technological vanguard, exemplified by innovations such as 3D printing and exoskeletons, is essentially reducing the industry's reliance on manual labor, a development that addresses the threat of labor shortages while also enabling efficiency in construction processes [28].

The transformational potential of AI scheduling programmes, as strongly advocated by industry expert Rene Morkos, deserves full recognition. It is noted that adherence to such AI-driven programmes is expected to provide substantial benefits, including a 16% reduction in average project length and an 11% reduction in labor expenses [29]. As a result, this technological integration emphasizes the construction industry's dedication to increasing efficiency and cost-effectiveness.

The imminent talent vacuum caused by the upcoming retirement of a significant portion of the construction industry's personnel is a growing issue. Therefore, AI and machine learning algorithms appear as vital tools for optimizing labor allocation across diverse projects, providing a long-term solution to the skill [22, 30].

In addition, it is observed that in the construction industry, autonomous cars play a critical role in the continuous monitoring of project progress, providing stakeholders with real-time data

on areas at risk of slippage and needing more labor resources [31].

Despite these technical advances, a notable gap emerges: the data connectivity between human labor and technology interfaces remains insufficient, an issue that is especially noticeable in an industry known for its labor-intensive operations. To address this issue, efforts are being made to promote digital solutions across the construction lifecycle. The integration of sensors and the use of smart wearable technologies are important components of this revolutionary vision, with the promise of a more fluidly integrated and efficient building process [32].

As is evident, these studies demonstrate that AI improves labour productivity in construction through productivity prediction, reduced reliance on labour-intensive tasks, automation, and workforce optimisation.

Quality Control

Quality improvement appears to be a recurring subject in construction studies; in the construction industry's quest for perfection, the confluence of cost and quality remains a critical factor. The prolific development of unstructured data in the form of photographs, videos, and different reports is becoming increasingly common in the construction industry. The strategic incorporation of this data into Building Information Modelling (BIM) systems, in conjunction with the use of advanced AI techniques, emerges as a transformative approach to optimizing site performance across critical domains such as planning, design, safety, quality, schedule, and cost [27]. The urgent need for the development of holistic site analytics solutions driven by AI and cloud-based real-time analytics is a key subject that emerges in this context. Such solutions offer to improve quality control and match building projects with set performance goals.

Kim et al. [33] developed a multi-sensor deep-learning approach for framework-distortion inspection, thus reducing data-acquisition time. This, at the same time, enabled maintaining an average angular error of 0.28° . Deep-learning approaches have also been applied to visual defect detection in construction, in particular, in buildings and infrastructure. Using this model, Hacıfendioğlu et al. [34] detected masonry cracks. Similarly, applying the same model, Lee et al. [35] and Zheng et al. [36] identified tunnel-surface defects. Zhao et al. [37] further coupled deep learning with computer vision to investigate defect detection in additive construction and real-time quality monitoring. In addition, Zhang et al. [38] demonstrated a UAV-based approach to tunnel inspection. These studies show that AI can improve the speed, precision, and labour efficiency of construction in quality control.

The integration of AI-driven chatbots suited to construction sites is a significant resource for project managers and other stakeholders, allowing real-time information on site operations and therefore improving situational awareness and decision-making [5, 39, 40].

The application of Internet of Things (IoT) technology reveals novel techniques to real-time risk monitoring in construction. For example, an IoT-based solution employs cloud database services, wireless sensors, and fuzzy logic to efficiently regulate product quality and occupational safety concerns in cold chains, highlighting the critical role of technology in improving construction site quality management [41, 42].

Finally, AI-powered chatbots created expressly for supply chain management systems provide a streamlined channel for getting essential information, making them a vital tool in the current dynamic construction [43–45]. As such in the context of current construction scenario integration of AI chatbots appears serves as driver enhancing transparency and sustainable growth of construction industry fostering innovation in organizational culture in which the effective decision making and quality of communication transitions into a new stage.

These findings demonstrate that AI strengthens and enhances construction quality control by detecting and localising defects, automating inspection enabling faster, more precise and consistent quality assessment.

Table 2 summarizes the principal applications discussed above and their potential implications for construction practice in Kazakhstan.

Table 2. Thematic synthesis of selected studies — Efficiency

Note: Reference numbers correspond to the bibliography. Implications for Kazakhstan are the authors' analytical proposals; they are not measurements from the cited studies.

Studies and references	Technology and application	Synthesis from the manuscript	Implications for Kazakhstan
Salih & El-Adaway (2024, 2025) [8, 9, 46]	AI and construction technologies. Project time, cost and management performance.	The synthesis links technology adoption with improved monitoring, decision-making and coordination of project objectives.	Assess schedule and cost outcomes against a documented project baseline; account for organizational readiness.
Son & Khoi (2023) [14]; Yilmaz & Dede (2023) [15]; Aminbakhsh & Ahmed (2024) [16]	Optimization algorithms. Construction scheduling and competing project objectives.	The studies address scheduling trade-offs. Work continuity is explicitly included in the Son and Khoi formulation.	Define project-specific objectives, precedence relationships and resource constraints before applying optimization.
Gopi Krishna & Dinesh Kannaa (2024) [17]; Galeazzi & Gonçalves e Silva (2024) [18]	Robotics and AI-assisted welding. Automation of repetitive construction and fabrication tasks.	The synthesis identifies robotics and automated welding as routes to more consistent execution and reduced reliance on repetitive manual operations.	Evaluate task suitability, equipment costs, operator skills and site safety before deployment.
Sriram et al. (2025) [19]; Du et al. (2024) [20]	BIM, decision support and data interoperability. Information-based construction decisions.	The cited works concern BIM-driven decision support and BIM/IFC data readiness for AI integration.	Check model completeness and data exchange before selecting an AI application; define the decision the model must support.
Adhikari et al. (2024) [21]; Sadeh et al. (2024) [22]	Construction digitalization. Productivity and responses to labor shortages.	These studies frame digitalization and technology adoption as responses to workforce constraints.	Measure labor hours and output at task level; include training and adoption requirements in pilot evaluations.
Lim et al. (2024) [23]; Chen et al. (2025) [24]	Machine learning and AI applications. Activity-level productivity and	These reviews provide context for productivity prediction, resource	Select a defined construction activity and verify the availability of representative local data.

	infrastructure construction.	allocation and AI applications in construction.	
Sadatnya et al. (2023) [25]; Taha et al. (2025) [26]	Machine learning; explainable prediction. Crew productivity and rebar-fixing productivity.	The cited applications concern prediction from daily work reports and estimation of productivity in rebar-fixing tasks.	Standardize site records and test predictions on separate projects; examine whether explanations are useful to site managers.
Hossain et al. (2020) [28]	Construction 3D printing. Changes in labor demand and task composition.	The synthesis links automation with reduced reliance on some manual tasks and with changes in required workforce skills.	Assess changes in crew composition, training needs and supporting tasks; do not equate automation with elimination of all labor.
Kim et al. (2024) [33]	Multi-sensor fusion and deep learning. Inspection of geometric distortion.	The cited work describes automated distortion inspection and reduced data-acquisition effort.	Validate measurement performance against an independent geometric survey under representative site conditions.
Hacıfendioğlu et al. (2023) [34]	Deep learning with images. Crack detection in historical masonry.	The cited work presents an application of automated visual crack detection.	Use representative images of local masonry; retain engineering assessment of crack causes and structural significance.
Lee et al. (2023) [35]; Zheng et al. (2024) [36]	Deep learning with tunnel images. Detection of tunnel surface and lining defects.	The cited applications support automated identification of visible defects in tunnel inspection imagery.	Test across lighting, moisture and surface conditions; distinguish visible-defect detection from assessment of hidden damage.
Zhao et al. (2024) [37]	AI-based visual monitoring. Quality monitoring in additive construction.	The cited work describes real-time monitoring and defect detection during additive construction.	Define detectable defects and acceptance criteria; connect monitoring outputs to a documented inspection procedure.
Zhang et al. (2024) [38]	UAV-based automated inspection. Tunnel surface defect inspection.	The cited work presents automated tunnel inspection using an unmanned aerial vehicle and a field test.	Assess access, image coverage and operational safety; require engineering review of identified defects.

Implications for Kazakhstan

The fast growth of AI technology in the twenty-first century has had a significant influence on different parts of industry and business. AI, in particular, has emerged as a potent tool for solving several crucial concerns, including efficiency and cost reduction, labor and management, quality control, and safety, as the literature suggests. The core question of this paper is about the

revolutionary potential of AI and its influence on Kazakhstan's construction sector. It focuses on major aspects of Efficiency, Labor and Quality Control. The findings provided here highlight the significant consequences of incorporating AI into the Kazakhstani construction sector. Kazakhstan ambitiously implemented industrialization policy; as a result, two programs have been developed: Accelerated Industrial and Innovative Development Program for 2010-2014 (hereinafter referred to as the SPFIID); Industrial and Innovative Development of the Republic of Kazakhstan for 2015-2019 (SPIID); and BIM adoption in 2016 under the umbrella of Technology of Information Modeling of Construction Facilities (TIMCF). Though the programmes have already been accomplished, Kazakhstan's policy in industrialization will continue, since the industrial sector accounts for a sizable portion of the country's Gross Domestic Product (GDP). The industrial complex generated around 28% of Kazakhstan's GDP in 2014 [47].

In the context of industrialization policy, it becomes clear that using AI's potential is critical for Kazakhstan's construction sector, providing a route towards increased efficiency, cost savings, and greater quality control. Construction activity frequently increases as industrialization proceeds. This is because the expansion of industries, manufacturing, and infrastructure development, all of which are critical components of industrialization, requires the construction of new buildings, factories, warehouses, and infrastructure. As such, by providing suitable infrastructure and facilities for industrial expansion, the construction industry plays a pivotal role in assisting the country's industrialization efforts. As a result, industrial growth has a direct and beneficial influence on the construction industry since it produces demand for construction projects and services. As a result, the industrial sector's dynamics have a significant impact on the country's economic growth rate.

Efficiency

Across the reviewed literature, efficiency in construction encompasses productivity, schedule, resource use, cost, quality, safety and decision-making. Along with process mining, optimisation, robotics, automation, BIM, and generative AI, these reviewed studies, more specifically Salih and El-Adaway [8, 46] addressed these aspects comprehensively. Collectively, the findings demonstrate that AI can improve prediction, monitoring, automation, coordination, and resource allocation. However, it is important to note that these benefits highly depend on digital infrastructure, data quality, workforce capabilities, structural readiness and alignment between AI tools and construction project needs.

When we explore the significance of these findings in the context of Kazakhstan, we may see an environment suitable for an AI-driven construction industry revolution. As the global construction sector reaps the benefits of artificial intelligence in terms of efficiency, cost reduction, and enhanced resource management, Kazakhstan may use these technologies to its own building projects. The capacity of AI to improve supply chain management, lower operating costs, and assure safety and security meshes nicely with Kazakhstan's dynamic construction sector.

In an era where competition is severe and organizations are continuously looking for ways to optimize their operations, artificial intelligence (AI) provides a promising path for attaining unprecedented levels of efficiency and cost reduction. Predictive analytics and automation powered by AI have transformed resource allocation, supply chain management, and production planning. Furthermore, AI systems can analyze big data using machine learning algorithms to provide insights that assist companies and organizations simplify operations, reduce waste and maximize resource utilization.

It is important to note that incorporating AI into Kazakhstan's construction sector is in line with the country's digital transformation strategy. The government's 2013 Information

Kazakhstan-2020 Programme lays the framework for the country's digital transformation, concentrating on information infrastructure, open government institutions, and enhanced public administration. Kazakhstan's Digital Kazakhstan Programme, launched in 2017, focuses on digitalizing economic sectors and cultivating a digital state to accelerate economic development and improve quality of life. This holistic integration of AI not only supports the Kazakhstan's national policy but also provides substantial benefits to the construction industry in terms of resource management, efficiency and cost reduction. The ability of AI to improve supply chain management, cut operational costs, and assure safety and security is a right match for Kazakhstan's dynamic construction sector.

Kazakhstan, like many other countries, is confronted with the issue of increasing competitiveness and the ongoing pursuit of operational excellence. Kazakhstan may put itself on the cutting edge of innovation by implementing AI solutions in construction, leading to more efficient, cost-effective, and sustainable building practices. For instance, in the manufacturing industry, AI-powered predictive maintenance may dramatically minimize downtime and costly unplanned repairs. AI-powered demand forecasting can help businesses manage inventory more effectively, lowering carrying costs and stockouts. AI-driven demand forecasting, for example, helps simplify material procurement, minimizing delays and cost overruns. Also, AI-powered energy management systems can optimize resource utilization, support sustainability goals while lowering operating costs. In summary, the article's findings open the path for Kazakhstan to embrace AI as a revolutionary force in the construction sector, enhancing efficiency, lowering costs, and fostering project delivery excellence.

Labor productivity

As far as labor productivity is concerned, the changing workplace landscape, significantly affected by artificial intelligence (AI), is having a dramatic impact on the nature of work itself, and this shift is very relevant to Kazakhstan's context. As has been mentioned the construction industry is one of the core sectors contributing to employment in Kazakhstan. In the construction sector the small and medium-sized enterprises (SMEs) play a crucial role in minimizing unemployment by creating job opportunities [48]. AI has emerged as a critical facilitator for remote work and effective labor management, a development with significant ramifications for both domestic and foreign workforces [49]. AI-powered solutions are critical for sustaining collaboration, productivity, and oversight, especially as remote work becomes more common. In this environment, AI-powered project management and collaboration solutions provide real-time insights to teams while improving communication and enabling seamless coordination across geographical borders. Furthermore, AI chatbots and virtual assistants contribute to greater employee assistance, reducing the pressure on HR and IT departments, a trend that is expected to continue.

In addition, the use of AI-powered site service management systems with such features such as route optimization, predictive scheduling and remote diagnostics has the potential to not only enhance field operations efficiency but also lower labor costs associated with travel time and maintenance.

As is demonstrated the reviewed literature identifies direct mechanisms through which digital technologies and approaches can influence labour productivity. These mechanisms include optimising workforce allocation, automating labour-intensive tasks, predicting crew productivity and improving coordination between digital systems and workers [21–26, 28]. More importantly, these imply workforce transformation rather than the direct replacement of construction workers.

This is because productivity gains depend on workers' capacity to interpret, operate and collaborate with AI-enabled technologies.

As the global construction landscape focuses on machine learning, optimization, robotics, and AI scheduling, it stands to reason that Kazakhstan's construction sector can also benefit from these advancements to address labor shortages, improve efficiency and meet rising demand for sustainable infrastructure. The ability to optimize labor allocation within building projects using real-time data.

However, in Kazakhstan, as in many other countries, there is a continuing need to bridge the data gap that separates human labor from technical solutions. While Kazakhstan has achieved tremendous progress in its digital transformation initiatives, social programmes that bridge the data gap between human labor and technology solutions are still needed. Existing programmes, such as those focusing on education and workforce development, should be strengthened to achieve this aim. Therefore, at the Digital Bridge 2025 forum, President of Republic of Kazakhstan Tokayev proposed establishing an AI university to train professionals and drive innovation [50]. These programmes can emphasize the need for digital literacy and skill development in order to guarantee that the country's workforce is ready to capitalize on the full potential of AI and technology in a variety of industries, including construction. This collaboration will assist not just the building business, but also Kazakhstan's general socioeconomic growth.

This initiative emphasizes the significance of incorporating AI and digital solutions into the construction ecosystem, opening the door for a more streamlined and efficient approach to constructing projects. As Kazakhstan's construction industry embraces artificial intelligence and digital transformation, it will be better positioned to meet and address the challenges of the workforce and achieve advanced levels of efficiency and sustainability, ultimately contributing to the country's development and competitiveness in the global arena.

Quality Control

Based on our review article results, it is clear that AI's disruptive potential extends beyond industry-specific applications, as emphasized in many areas. According to our findings, using AI-driven quality control methodologies has demonstrated amazing performance in improving product quality, minimizing risks, and assuring customer satisfaction internationally.

These study findings show that AI is enhancing and, in particular, shifting construction quality control from manual inspection towards continuous, automated monitoring. Such technologies and approaches as deep learning, multi-sensor and UAV-based systems, and computer vision, support more precise and timely detection of structural distortions, surface defects and cracks in buildings and infrastructure [33–38].

While the State Programme for Industrial-Innovative Development, which ran from 2010 to 2014 and from 2015 to 2019, set the foundation for a robust industry in the state, it is critical to recognize that certain sectors, such as quality control, are still in their infancy. According to an international study, integrating AI technology can result in major benefits. This implies that Kazakhstan's existing industrial strategies can benefit from AI-driven quality control advancements, aligning with global industry standards and improving its competitiveness.

It is important to mention that AI technologies are transforming traditional quality control methods by adding predictive and preventative approaches. Visual inspections integrated with AI systems may detect faults and barriers in production processes quickly, substantially lowering the risk of poor items reaching customers. Furthermore, AI-enhanced analytics can monitor and regulate quality parameters, allowing for real-time modifications and reducing production variances.

AI-driven diagnostic tools and predictive analytics in healthcare aid in spotting possible concerns before they escalate. AI algorithms, for example, may analyze patient data to anticipate illness outcomes, improving treatment quality and lowering medical mistakes.

Conclusion

In conclusion, this review study emphasizes the revolutionary potential of AI and technology in the construction industry. The incorporation of AI techniques into the building processes holds the potential of improved performance in a variety of areas, including quality, safety, and efficiency. The incorporation of real-time data analytics, IoT, and AI-powered chatbots emphasizes the evolving landscape of construction, in which data-driven decision-making, quality optimization, and supply chain efficiency play critical roles in shaping the industry's future.

However, it is important to note these benefits are not directly related to the automatic outcomes of AI adoption. The realisation of these technologies and approaches depends on digital infrastructure, workforce capabilities, reliable data, and organisational readiness. This indicates that these conditions are relevant across different contexts, with Kazakhstan providing an illustrative case of how rapidly developing emerging digital economy might translate aforementioned global AI developments into construction practice.

In order to adopt AI technologies, it is critical to recognize their potential for making companies and society more efficient, cost-effective, and safe. Due to generous government investment in infrastructure, the construction sector in Kazakhstan is predicted to rise by 6.7% in real terms this year, before averaging 5.5% every year by 2026 [51]. Therefore, the role of AI is crucial to realize and implement the government's national plan in relation to the construction sector. The combination of real-time data analytics and AI-powered chatbots emphasizes the construction industry's shifting landscape. Data-driven decision-making, quality optimization, and supply chain efficiency will be critical in Kazakhstan. As the literature review demonstrates, the potential of integrating AI is crucial in the construction sector and this demonstrates important implications for the construction industry of Kazakhstan.

Limitations and Recommendations

However, the international practice of using AI in construction industry demonstrates high potential integrating it in construction processes the context of Kazakhstan may make this transition difficult. First of all, at the macro level the country has limited access to technological resources, sustainable uncertainty, systemic fragmentation of labor market. As such the use of AI is not without challenges, such as the high cost of advanced IT infrastructure, the lack of standardized performance measurement frameworks, and trust and communication barriers within organizations in Kazakhstan. Therefore, despite the attractiveness of these global cases in effective AI use realization and feasibility of such approaches in Kazakhstan requires holistic approach, institutional reform and sustainable adaptation to technological environment. However, despite the international study findings offer valuable insights for Kazakhstan, application of these technologies and approaches should be adapted to the country's specific organisational, technological and workforce conditions. Therefore the future research should compare how Kazakhstan and different countries address common challenges in adopting AI in construction sector. As such, based on the literature review findings and identified limitations, three key recommendations for Kazakhstan's construction sector are presented. Following these recommendations, Kazakhstan's construction industry can utilize the transformative potential of AI for enhancing efficiency, labor productivity and quality in the construction sector contributing

to the country's construction industry development and competitiveness on a global scale. The first recommendation includes that at a macro systems level Kazakhstan needs to adopt holistic approach in AI integration embracing all strategic sectors. Aligning to country's national policy, the construction industry needs structural change to proactively use AI-powered technologies to improve productivity, optimize resource allocation and cut costs. This involves the use of AI-powered project management, machine learning-driven scheduling systems, predictive analytics, digital twins and robotics to enhance operations. Secondly, Kazakhstan needs to invest in workforce development programmes with focus on digital skills and AI competence to solve labor shortages and skill gaps. This will mitigate the sector to use on AI breakthroughs. Finally, Kazakhstan needs to incorporate AI-powered quality control approaches into building processes to detect any potential flaws and manage quality standards. This will provide guarantees that projects meet high-quality requirements while also minimizing the risks.

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The contribution of the authors

D.O. Bazarbayev: conceptualization of the review, formulation of the research question, development of the review methodology, supervision, and critical revision of the manuscript.

D.K. Zhumadullaev: analysis and interpretation of the reviewed literature on construction efficiency, synthesis of the findings, and critical revision of the corresponding sections.

L.I. Ramatullaeva: analysis and interpretation of the reviewed literature on quality control, development of the discussion of these findings, and critical revision of the corresponding sections.

S.S. Shukirova: literature search and screening, extraction and organization of information from the selected publications, and preparation of the initial manuscript draft.

B.T. Uakhitova: analysis and interpretation of the reviewed literature on labor productivity, assessment of the implications for Kazakhstan's construction sector, and critical revision of the corresponding sections.

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Information about the authors:

Bazarbayev D.O. – main and corresponding author, PhD, Associate professor of L.N. Gumilyov Eurasian National University, 2 Satbayeva str., 010000, Astana, Kazakhstan

Zhumadullaev D.K. – PhD, Associate Professor, M. Auezov South Kazakhstan University, Shymkent, Kazakhstan.

Ramatullaeva L.I. – Head of the Department of the Educational Program “Life Safety and Environmental Protection”, Candidate of Technical Sciences, Associate Professor, M. Auezov South Kazakhstan University, Shymkent, Kazakhstan.

Shukirova S.S. – PhD Doctoral Student, M. Auezov South Kazakhstan University, Shymkent, Kazakhstan.

Uakhitova B.T. – PhD, Associate Professor, Head of the Department of “Metallurgy and Mining”, K. Zhubanov Aktobe Regional University, Aktobe, Kazakhstan.



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