Investigation on the Adoption of Autonomous Construction: A Case Study in Construction Companies

Norhana Mohd Aripin, Aimy Amiera Ainna Ahmad Pirdaus, Haziman Zakaria, Kamarulzaman Mahmad Khairai, Mohd Yusrizal Mohd Yusoof
Universiti Malaysia Pahang Al-Sultan Abdullah, Malaysia

International Journal of Business Sustainability

Volume: 1,
Issue: 3, 2026

Received: 19 December 2025
Revised: 19 December 2025
16 February 2026
Accepted: 16 February 2026
Published: 31 March 2026

Abstract

Purpose: The Malaysian construction industry is shifting towards Construction 4.0 with autonomous construction to improve productivity and support national sustainability goals. This research examines the benefits and critical barriers to the adoption of autonomous construction in Malaysia.

Design/methodology/approach: This research employed a qualitative methodology, using semi-structured interviews with six informants from construction companies in Malaysia who had relevant experience in planning, execution, or management of construction within their organizations.

Findings: The benefits of autonomous construction were identified, including time saving, improved quality, enhanced safety, cost effectiveness, and reduction in manual labour dependency. In addition, high costs, a lack of skilled workforce, resistance to change, technological maturity, and job security concerns were identified as the barriers to adopting autonomous construction.

Limitations and Research implications: This study implied qualitative approach using semi-structured interviews, which limits the generalizability of the findings. As the research focused on Malaysia, the results may not reflect conditions in other regions. The absence of quantitative data also makes it difficult to measure the extent of the benefits and barriers of autonomous construction.

Practical Implications: Findings of this research offer guidance to industry stakeholders and policymakers to design strategies, targeted training programs, and policy revisions to facilitate the industry's movement towards the adoption of autonomous construction.

Originality/value: This study provides empirical evidence on the adoption of autonomous construction in Malaysia, offering context-specific insights into its benefits and barriers that remain underexplored in existing literature.

Keywords: Autonomous Construction, Construction 4.0, Sustainability, Construction Industry

Introduction

The construction industry is transforming due to infrastructure and industrial development, which has forced organizations to adopt automation as construction projects become increasingly complex and require shorter deadlines (Shafei et al., 2025; Su et al., 2025). From the perspective of business sustainability, this transformation enables the creation of long-term value through higher productivity, operational efficiency, and resource optimization. the rising technologies in Construction 4.0. In response to technology transforming the construction field, the Kementerian Kerja Raya (KKR), along with the Construction Industry Development Board (CIDB), has launched the Construction Strategy Plan 4.0 (2021–2025) to strengthen and transform the Malaysian construction industry into a competitive and productive industry (Shafei et al., 2025). This is a five-year short-term plan by CIDB, to upgrade the construction industry in this challenging environment. This strategy has been built in line with the Shared Prosperity Vision 2030 and the National Industry 4.0 Policy (Industry4WRD),

e-ISSN: 3110-7737
DOI:
10.25299/ijbs.2026.26441

National Internet of Things Strategic Roadmap, the Malaysian Smart City Framework, and the Digital Economy Policy to ensure that the construction industry keeps improving, thus supporting the country's economic growth while promoting long-term environmental and economic sustainability (Yildirim et al., 2025).

Construction 4.0 refers to the application of Industry 4.0, which focuses on computers, cyber-physical systems (CPS), and the integration of technologies such as artificial intelligence (AI), IoT, and robotics in the construction industry (Shafei et al., 2025; Statsenko et al., 2023). Autonomous construction, a subset of Construction 4.0, can be defined as the application of automated techniques, machines, tools, or systems in construction activities that operate independently without direct human intervention (Dhamak et al., 2025; Frank et al., 2019). Autonomous construction includes robotic equipment, automated concrete block laying, and robotic surveying systems (Adebayo et al., 2025; Zhao et al., 2022). Technologies are advancing, and there is a transformative wave moving the construction industry beyond traditional practices and setting new standards for efficiency as well as sustainability. In turn, this wave has initiated technical progress and a paradigm shift in the way construction projects are planned, monitored, and completed (Basir, 2025; Zhao et al., 2022). From the perspective of business sustainability, autonomous construction supports long-term organizational performance by operational waste reduction and safety improvement, besides energy efficiency enhancement. Apart from productivity improvement, material waste can be minimized by autonomous construction, hence, environmental sustainability can also be enhanced since rework is minimized and energy consumption is optimized during construction activities (Abbasnejad et al., 2024; Su et al., 2025).

Nonetheless, the construction industry faces various limitations to adopting autonomous construction, and insufficient research has been conducted to address these challenges. The CIDB Malaysia has laid strong foundations by planning and constructing pilot programs, as well as organizing awareness initiatives to promote autonomous construction. Yet, contractor and organizational adoption rates remain low, with an average expenditure of 23% on new technology (Yildirim et al., 2025). Despite these efforts, the transition from traditional construction methods to fully autonomous systems has been gradual. Malaysian contractors primarily achieve semi-automation levels when implementing autonomous construction technologies (Jaafar et al., 2024). Malaysia ranks as the second-leading nation in the digital use of Construction 4.0 according to a survey of six Asia-Pacific countries, but the emphasis remains mainly on BIM, AI safety systems, and modular building practices, highlighting the importance of the research to further investigate the low adoption of autonomous construction implementation.

Previous research from Murguia et al. (2026) develop a comprehensive conceptual model for Construction 4.0 implementation from an innovation management perspective, the study primarily emphasizes capability stages, business model configurations, and strategic transformation rather than examining technology-specific adoption in the construction industry. In particular, autonomous construction in terms of benefits and barriers was not empirically explored from the perspective of industry practitioners. Similarly, Dhamak et al. (2025) provide a comprehensive overview of Construction 4.0 technologies and map their implementation trends. However, the focus remains on technological classification and strategic roadmapping rather than investigating how construction firms evaluate and experience the benefits and barriers of autonomous construction. Therefore, despite the growing body of literature on Construction 4.0, there is limited empirical evidence specifically addressing the adoption of autonomous construction, particularly within emerging economies such as Malaysia.

In addition, to confirm this practical problem, a preliminary study was conducted through an interview with CIDB personnel to explore the level of autonomous construction adoption in Malaysia. Feedback from the preliminary study revealed that while the knowledge about autonomous construction is rising, its use in practice is still not widespread. Not many participants reported using autonomous construction, pointing out that the industry is still in the early phases of its transformation. These findings indicate a gap between technological awareness and sustainable implementation, highlighting the need for strategic interventions that support long-term business sustainability. These preliminary findings highlight the importance of conducting this study to further explore the factors influencing the adoption of autonomous construction and to support its effective implementation in the construction industry.

International Journal of Business Sustainability

Volume: 1, Issue: 3, 2026

Hence, the objectives of this study are:

1. To determine the benefits of adopting autonomous construction among construction companies in Malaysia.
2. To examine the barriers to adopting autonomous construction among construction companies in Malaysia.

This research is structured as follows. The first section provides an introduction, outlining the research problems and objectives. Next, the literature review relates to the construction industry, economic development, current challenges, and the history of adopting digital technologies in Malaysia. Following that, the research methodology used in these studies is explained. The discussion section covers the findings of the research. Lastly, the study discusses the benefits and barriers of implementing autonomous systems and suggests future research.

Literature Review

Construction Industry in Malaysia

The Malaysian construction industry in Malaysia has greatly improved the national economy and provided jobs, which have brought both public and private funds (Hwang et al., 2020; Yildirim et al., 2025). The construction sector plays a strategic role in balancing economic growth with long-term environmental and social responsibilities. However, the industry still faces a productivity gap, as its reliance on traditional labor-intensive methods raises concerns about long-term sustainability (Farsangi et al., 2025). In 2016, Malaysia launched The Construction Industry Transformation Programme (CITP) to help the construction industry become sustainable and compete with international competitors (Rani et al., 2023). The construction industry aimed to deliver a 6.0% average Gross Domestic Product (GDP) contribution annually as part of Vision 2020 to help Malaysia shift from developing to developed nation status (Hwang et al., 2020). The industry's expanding footprint delivers sustained effects on overall employment numbers and economic conditions, although it has persistently failed to meet this target (Chan & Abdul-Aziz, 2020; Shafei et al., 2025).

The construction sector builds dynamic relationships between different industries through its adoption of socioeconomic infrastructure development for essential facilities (Shafei et al., 2025). The infrastructure functions as the foundation for multiple structures that enhance standards of living. Modern infrastructure and efficient methods allow Malaysian firms to execute complex infrastructure projects (Alnajjar et al., 2025). In addition, the sector also contributes significantly to carbon emissions and resource use, making the integration of autonomous construction technologies important in reducing environmental impact while ensuring sustainable infrastructure development (Melenbrink et al., 2020).

The construction industry in Malaysia experienced growth from Q1 2020 to Q2 2024, with the private sector contributing 60.8% of the total work value. The pandemic prompted the sector to implement technology and innovation to reduce workforce use and enhance productivity

e-ISSN: 3110-7737
DOI: 10.25299/ijbs.2026.26441

(Kim et al., 2024). Moreover, civil engineering and non-residential buildings were the most significant sub-sectors, with civil engineering work accounting for 39% of the total construction work completed. Non-residential buildings, including commercial and industrial buildings, accounted for 27.3% of the work completed. Maintenance and installation services contributed RM4.3 billion (11.1%), while residential buildings represented 22.6% due to growing housing demand. The private sector continued to be the key contributor, contributing RM23.6 billion or 60.8% of the value. This growth demonstrates Malaysia's improving economic conditions and continued investment in infrastructure, reinforcing the central role of the construction sector in national development. However, with this rapid growth comes increased energy demand, making digital and autonomous construction a potential solution for optimizing energy use and reducing the environmental impact of large-scale projects (Asif et al., 2024).

Economic Impact and Role in National Development

The role of economies in national development is influenced by factors such as natural resources, household savings, digital economy, sub-national government quality, and financial sector adequacy (Kim et al., 2024). In this context, Construction 4.0 is the integration of digital technologies that would increase productivity with fewer negative externalities on the environment as a support to sustainable economic development. High-quality economic development is inspired by the digital economy, especially in areas with better institutional environments. Based on the concepts of Industry 4.0, BIM, AI, IoT, and blockchain technology represent digital advancements included in Construction 4.0 (Kim et al., 2024). These advancements change roles and skills in the construction industry (Shafei et al., 2025; Statsenko et al., 2023). Construction is a specialized sector that provides investment opportunities and contributes to national social and economic objectives. Construction 4.0 integrates technology into processes, such as automation machines, pre-fabrication methods, and AI tools (Balasubramanian et al., 2021). This leads to higher employment, business growth, and improved economic funds. Malaysian businesses have significantly adopted digital technologies, with an average expenditure of 23% on new technology. In addition, the adoption of such technologies reduces waste, enhances energy efficiency, and contributes to achieving Malaysia's climate change commitments and the UN Sustainable Development Goals (Asif et al., 2024).

In fact, government funding and policies are crucial for the construction industry's growth, with appropriate strategies and timely investments ensuring economic gains (Wong et al., 2010). Proper policy and regulatory changes, including institutional and regulatory changes, procurement changes, and local content regulations, optimize the sector's operations (Oti-Sarpong et al., 2022). A shortage of adequate building infrastructure hinders the performance of the sectors of a country, encourages an underperforming economy, lowers the living standards, and facilitates the imbalance in incomes. Effective management of the construction sector enables a higher standard of living, increasing tourism, currency circulation, and employment throughout the country (Fei et al., 2021).

Current Challenges and Limitations in the Industry

The construction sector has often been slow to adopt new technology and skills, resulting in poor project efficiency and worker productivity levels. The construction industry, which is often cited as being among the least digitized sectors, has been going on as usual for so long (Frank et al., 2019). Other than that, common progress management techniques normally used in construction sites are not precise and time-effective. It involves a lot of manual work and labor-intensive (Musarat et al., 2024). It also suffers from many problems that need identification and resolution (Dehdasht et al., 2022). The construction project must meet deadlines, cost requirements, and the level of quality desired, but due to a lack of issues, it often causes project delay and estimation cost overrun (Balasubramanian et al., 2021). Moreover, the construction industry is overburdened by costs, time, hazards, and waste (Shafei et al., 2025).

Time wastage and inefficiencies, excess material consumption, and safety hazards are among the several issues that persist at construction sites and lead to a profound effect on society, which affects the construction industry and the global crisis (Delgado et al., 2019). These inefficiencies impact financially and environmentally, as wasted materials and energy consumption contribute significantly to ecological degradation (Yitmen et al., 2025). Despite the rapid development of digital technologies, it reflects a tension between technological and practical implementation. While technological tools promise efficiency and precision, construction firms continue to struggle with several hurdles which may hinder full-scale adoption.

International Journal of Business Sustainability

Volume: 1, Issue: 3, 2026

Maintaining high-quality construction standards is critical, but the construction industry faces obstacles in achieving continuous quality control. The issues include the technical and work-culture factors, where there is still a lack of standardization, and limited operation of advanced equipment, such as robotics and automation (Delgado et al., 2019). The construction projects are complex due to the involvement of a lot of stakeholders in the project. An unpredictable environment of a project also creates uncertainty level of a project, adding complexities to the project (Musarat et al., 2024). The construction industry’s fragmented nature and current short-term emphasis have hindered its ability to innovate (Alaloul et al., 2022). This further delays the adoption of technologies that reduce waste generation, improve resource utilization, and align the industry with green construction practices (Yitmen et al., 2025).

History and development of autonomous construction technologies

Over time, autonomous construction technology has evolved from early automation and the use of prefabricated components to the deployment of specialized robots for on-site construction tasks. Current efforts focus on improving coordination, adaptability, motion planning, and human–machine systems to meet industry demands and address environmental challenges (Frank et al., 2019). The industrial revolution made changes to how people work and live, as well as to economies and societies (Zhao et al., 2022). The phase of the Industrial Revolution started with the invention and widespread adoption of the steam engine. It enabled the factories to operate independently of natural power sources like rivers, spurring massive urbanization and economic growth. Moving on to the second phase, where a wave of mass production powered by electricity where this revolution introduced in the 19th and early 20th centuries (Frank et al., 2019). The shift from steam to electrical power enabled more flexible, scalable, and safer industrial operations. The digital technologies like computers, the internet, and mobile phones were introduced as the third industrial revolution in the late 20th century (Frank et al., 2019; Zhao et al., 2022). Unlike previous eras, this time, revolutionaries included information technology in the growing fields of industrial technology. Developments in software, automation, and online communication enabled the world to connect and fueled the growth of the knowledge economy. With the fast changes brought by the fourth revolution, organizations must adjust their thinking and adapt to new situations.

On the fourth revolution, it was contributed by the introduction of CPS, which makes use of technologies such as AI, robotics, and nanotechnology (Aripin et al., 2023). The improvement of sensor technology, AI, and BIM has helped construction robotics for site building gradually develop (Staccioli & Virgillito, 2021). As a result, many single-task and combined robots began to be used on construction sites, enhancing the accuracy, efficiency, and safety of the work (Zhao et al., 2022). The historical context of mechanization significantly influences current autonomous construction technologies by providing a foundation of knowledge and

e-ISSN: 3110-7737
DOI: 10.25299/ijbs.2026.26441

experience in automating construction processes (Melenbrink et al., 2020). The mechanization of construction work, particularly in crane work and earthwork, has progressed since the mid-20th century (Vadukkumchery & Myneni, 2023). After World War II, Japan rapidly promoted mechanization to improve infrastructure, utilizing construction machinery from the United States and collaborating with overseas companies to re-establish domestic manufacturing.

The historical progression from basic mechanization to semi-automatic and now autonomous systems demonstrates a clear path of technological advancement shaping current practices. The adoption of emerging technologies in the construction industry will enhance human interactions with projects throughout their life cycle and management (Peng et al., 2025). In Malaysia, several autonomous machines are currently being adopted, such as automatic plastering machines, tiling machines, and bricklaying robots (Melenbrink et al., 2020). However, industry practices have mainly relied on automating typical earth-moving machines and the utilization of prefabrication to decrease site activity. These advancements improved productivity and provided opportunities to reduce construction waste, lower environmental disruption at sites, and optimize energy consumption, demonstrating the close link between technological change and sustainability outcomes.

Methodology

This research used qualitative approach using semi-structured interviews to obtain the participants' experiences and perspectives. It aims to understand the processes and patterns of development within studied case, focusing on "how" and "why" questions (Busetto et al., 2020). Quality assurance in qualitative research emphasizes trustworthiness, ethical integrity, clarity, and coherence. Researchers must investigate reliability, dependability, transferability, confirmation, and ethicality to ensure credible and valuable insights (Sargeant, 2012). The case study is useful across different disciplines, especially when the depth and context of phenomena are important (Yin, 1994). Case studies can generate new hypotheses and identify overlooked variables in previous research (McCutcheon & Meredith, 1993). However, critical selection bias can influence the research, and conclusions are usually contextual, limiting their generalizability to specific conditions. Despite these challenges, case studies remain useful in construction research for investigating specific phenomena and developing models for future applications. Furthermore, a case study provides practical guidance for designing, conducting, and completing research projects, contributing to knowledge on methodology (Yin, 2013).

A semi-structured interview was used with the following framework to achieve the research aim and gather detailed data and evidence. All research questions connected to the study are evaluated within the main questions segment, which considers question categories. During this semi-structured interview, the interviewer established standardized procedures while remaining adaptable to alterations in the interview process. The research employed purposeful sampling to select specific cases as they offer substantial and relevant data. This approach enables researchers to choose the case who are most aligned with the research questions and objectives (Yin, 2013). This sampling technique was chosen for two types, which are the case company and the individual (informants). For the case companies, the criteria are chosen based on the following key requirements. First, the company must be registered with the CIDB at least within grades G6 and G7. Second, the company should have operated for at least 5-10 years in the construction industry, and finally, have implemented or are in the process of implementing autonomous construction methods to provide practical insight. As for an individual, the respondent must hold a managerial position, such as a manager, department head, project executive, or operational manager. Following that, they are required to have at least five years of experience in their current position and be involved in the planning, execution, or management of construction in the organization.

Overall, a total of six interview sessions were conducted in this research. Data was collected until saturation occurred, which indicates that new insights were obtained. Although the number appears limited, the saturation of data was reached with six interview sessions, where no subsequent insight was collected with the last interview session. Additionally, this number is aligned with the proposal from Creswell et al. (2011) mentioning that the participants for the case study are suggested between 4 and 10 participants. The interviews were conducted with four construction companies in Malaysia. The companies were introduced through the CIDB personnel, who considered the companies to be relevant and potentially involved in technology-driven practices. The case companies have met the key requirement, meaning that the views were insightful and experience-based. Details for each informant are explained in Table 1. Each informant received the interview consent before the scheduled interview to improve the study's reliability. Each informant signed the consent form, which they returned to the research team. Additionally, an interview protocol was developed before the study began. The interview protocol was divided into three sections that comprised (1) headers, (2) major substantive questions, followed by (3) closing instructions.

International Journal of Business Sustainability

Volume: 1, Issue: 3, 2026

Table 1
Detailed Information of the Informants.

Informant	Position	Year of Experience	Experience in autonomous construction	Exposure to autonomous construction
A	Project Manager	10 years	Yes	Yes
B	Architect	5 years	No	Yes
C	Quantity Surveyor	6 years	No	Yes
D	Operation Manager	11 years	No	Yes
E	Site Engineer	11 years	No	Yes
F	Project Manager	13 years	No	Yes

This study uses thematic analysis to analyze the qualitative data. Thematic analysis is a method that helps researchers identify codes in the data by examining the meanings behind what informants say. The first step in data analysis was to transcribe and write the data in text format. Following that, based on the text format, the codes are found by paying close attention to keywords and how they reflect the informants' thoughts. During the initial coding stage, recurring concepts such as faster completion, reduced errors, high equipment cost, lack of technical skills, and job displacement concerns were identified. This helps them notice early patterns and select quotes that represent the study's main ideas. During this coding phase, short labels were given to sections of the data to summarize the meaning only. The analysis continues to conceptualize how investigators analyze keywords with codes, along with themes, to establish definitions of social phenomena using concept mapping as the main tool. These initial codes were subsequently grouped into broader themes reflecting benefits and barriers to the adoption of autonomous construction. A conceptual framework emerges from the study to display its outcomes, answer research questions, and demonstrate its value to academic literature. This analysis was conducted using ATLAS. 9 software for data interpretation and pattern search, coding comments for patterns, and categorizing images, sounds, and videos. The software also aids in searching using codes and combinations of the same.

Finally, to enhance trustworthiness, the member checking process involved sharing the summarized interpretations of the findings with the key informant (Informant A). This process was conducted to confirm the accuracy of the interpretation. This process allows the key

e-ISSN: 3110-7737
DOI: 10.25299/ijbs.2026.26441

informant to verify the accuracy of the themes and sub-themes proposed by the researchers. Informant A confirmed and agreed with the themes and stated that the themes accurately reflect the interviewee's views. Hence, no revision was made to the themes and sub-themes suggested by the researchers.

Results

The interview findings were analyzed to answer two research questions that identify the benefits and barriers to the adoption of autonomous construction among construction companies in Malaysia.

Benefits of Autonomous Construction Technologies

Based on the interview session, the benefits of autonomous construction in Malaysia have been identified, yielding five themes: time saving, improved quality, enhanced safety, cost effectiveness, and reduction in manual labour dependency. Supporting quotations related to this research question are outlined in Table 2.

Most of the participants highlighted that the automation could expedite the construction process, potentially leading to time saving for project completion. According to informant A, autonomous systems minimize waste and rework, improving the quality and durability of constructed buildings. Informant D supported and agreed that the continuous operation of robots alongside automated machinery produces faster output without requiring any rest periods, as compared with the human workforce, which can be limited by fatigue and subject to human error. Both informants have stated that autonomous construction technology is better for repetitive tasks and structured tasks.

The autonomous technology is a new way to improve quality by identifying defects early, maintaining consistent quality standards, and enhancing accuracy and uniformity throughout the project. Informants B and C both noted that using autonomous construction helps to avoid the errors that often occur with manual work. Informant F also claimed that using technology makes it possible to achieve accurate work on complex projects, boosting the quality in architecture and engineering.

The construction industry highlights the importance of safety in its operational activities. According to Informant A, they are using drones for the inspection of areas that are not easy to reach. This improves safety because workers do not need to be present in locations where they would be exposed to hazardous conditions. Based on the information from informants C and D, autonomous systems help in less manual labor in danger zones, thus, direct exposure of the workers to risks is minimized. The automation of these high-risk activities protects human capital and makes operations better. According to informant F, this approach simultaneously enhances safety by limiting human exposure to hazardous conditions and ensures project continuity by reducing delays associated with workforce limitations.

The integration of autonomous technologies in construction has been recognized as a means of reducing overall project costs. According to the informants, while the implementation of such technologies requires a substantial initial investment, the long-term benefits outweigh the expenditure. These benefits include enhanced worker productivity, reduced material waste, fewer rework requirements, accelerated project completion, and improved safety outcomes. Collectively, these advantages demonstrate that autonomous construction represents a sustainable and strategic solution for addressing the persistent challenges of cost, time, and quality within the industry.

Table 2
Quotation Related to the Benefits of Autonomous Construction among Construction Companies

Cluster No. and color	Representative Keywords
Time saving	"Autonomous construction can improve efficiency, reduce human errors, and complete work faster." "A project that usually takes a year might be completed in six months, ... Their quality is excellent, neat, and detailed."
Improved quality	"Compared to manual labor, it ensures higher consistency and standardization in the quality of work" "It delivers better and more standardized quality, provided the machines are properly calibrated. Automation is especially beneficial for extended work hours, which is crucial in contexts like Malaysia, where the typical workday runs from 8 AM to 5 PM and manpower availability is limited."
Enhanced safety	"It also helps to improve safety at construction sites as it reduces the need for workers to perform dangerous tasks." "There will be no critical incidents, and the risk will be low..."
Cost effectiveness	"No need for major investment. It cuts costs and is much cheaper and faster. It can work for 24 hours" "Honestly, it's all about cost-cutting. Companies are investing in automation mainly to reduce labor expenses. With this technology handling design processes and machines doing the physical work, there's less need for a large team on-site... That's a major reduction in salary costs, not to mention overheads like office space and admin."
Reduction in Manual Labour Dependency	"...use automated machinery like Autonomous Tunnel Boring. This helps reduce dependency on manual labor, increase safety and improve project timelines." "Yes, it saves labor and allows better planning of materials"

International Journal of Business Sustainability

Volume: 1, Issue: 3, 2026

Informants B and C said that the implementation of robots in construction work will make it more expensive, though it will save a lot of money in the end with reduced labor costs. Autonomous construction reduces the need for manual workers by implementing technologies that can automate some tasks that are now being performed by workers on-site. In connection to this, fewer workers who are directly involved in dangerous or monotonous operations reduce not only the direct cost of wages but also the expenses on benefits, insurance, and training costs. The reallocation of workers to other jobs also allows project managers to make worker utilization better, hence improving organizational efficiency.

Barriers to the adoption of autonomous construction

The analysis of barriers to adopting autonomous construction among companies in Malaysia revealed five key themes derived from informant responses. These include high cost, lack of skilled workforce, resistance to change, technological maturity, and job security concerns. Collectively, these factors are perceived as critical barriers to the widespread adoption of

e-ISSN: 3110-7737
DOI: 10.25299/ijbs.2026.26441

autonomous construction in the region. A detailed presentation of these themes, supported by quotations from the informants, is provided in Table 3.

Table 3
Quotations for Barriers to the Adoption of Autonomous Construction among Construction Companies

Cluster No. and color	Representative Keywords
High Cost	"Sometimes the cost goes over budget, ... If the project is small, using such technology may not be reasonable to use." "The biggest challenge is the high cost of purchasing and maintaining autonomous construction technology." "Construction 4.0 is really good, it has the desire, but most manufacturers don't seem to be able to afford it."
Lack of Skilled Workforce	"One major issue is the limited availability of workers with technical skills to handle automation." "Most of our workers are trained in manual work; automation requires extensive training." "If there's a malfunction, is there local servicing? How do we fix it? We'd have to rely on foreign services or limited local technicians." "We're still in trial and error with these technologies. And lack of skilled workers, who know how to use AI and autonomous."
Resistance to Change	"Resistance to change by our management is also one of the challenges." "I'm not against innovation, but we need proof it works before relying on it. Until then, I think many will stick with what they know."
Technological Maturity	"We're just starting with prefabrication. On the way to implementing autonomous construction, but not yet successful. We've looked at costing. It's fast but leads to high wastage. We've been facing on-site issues, including cracks that show the technology is not matured in enough." "We need evidence that it works reliably under our conditions. Otherwise, the investment might not be worth it just yet."
Job Security Concerns	"Another constraint is job security concerns among workers, as they fear losing their jobs to automation." "Those 5 to 10 people lose job opportunities... AI can replace them, it's better. But we need training and new policies." "I can only tell if using AI and autonomous, humans will have no jobs. AI can do everything... So, people are starting to lose jobs."

Budget constraints limit the capacity of contractors to adopt advanced technologies, particularly in smaller construction projects where the investment may be prohibitive. Beyond the initial costs, the additional expenses associated with maintenance, software updates, and the employment of specialized technicians further intensify the financial burden. Informants A and D highlighted the importance of careful planning, strategic alignment, and stakeholder readiness, stressing that inadequate planning can undermine value creation and even disrupt project outcomes. They further emphasized that the adoption of autonomous construction technologies should be contingent upon project size, client requirements, complexity, budget, and timelines. Successful adoption also depends on the availability of a workforce capable of operating and maintaining sophisticated equipment. However, participants noted that the industry continues to depend heavily on manual labour with limited technical training. This skills gap presents a significant barrier to the effective integration of automation, as workers may encounter difficulties in managing complex software systems and advanced machinery.

Informant D noted that the machinery currently in use is not fully automated, as skilled operators for programming, monitoring, and troubleshooting system operations are still limited. Supporting this perspective, Informant E emphasized that insufficient technical competencies among employees can disrupt project execution, resulting in recurring issues, reduced efficiency, and potential system failures. Informant E further highlighted the shortage of local expertise in maintaining and repairing advanced equipment, which often necessitates reliance on external specialists. This dependence not only increases operational costs but also serves as a disincentive for organizations considering investment in automation.

Technological maturity and the reliability of autonomous construction systems remain critical concerns for organizations. Informant C noted that significant risks are associated with the deployment of such technologies, as failures or underperformance could compromise safety, increase costs, and negatively impact project quality. Similarly, Informant B emphasized that the issue of technological maturity continues to challenge organizations, particularly with respect to the dependability and preparedness of autonomous equipment for consistent use on construction sites.

Moreover, introducing automation enhances workers' concerns about potential job displacement. Informant B has highlighted autonomous systems taking over human jobs, especially routine and unskilled tasks. Without retraining or upskilling, these workers face a high risk of being left behind in a tech-driven future. According to informant F, it also requires higher-level leadership to take charge, as both decision-makers and workers need preparation for change. Informant C mentioned that the innovative features of autonomous technologies could conflict with the systems and tools used in the current project management. As a result, processes cannot be combined easily, the same work needs to be repeated, and more is spent, making it less appealing for organizations that have little to spare.

Discussion

The implementation of autonomous construction technologies reveals that several challenges have slowed their adoption within the construction industry. Although autonomous construction is gaining global attention, its implementation in Malaysia remains limited. Based on the findings of this research, Figure 1 illustrates the interrelationship between the benefits and barriers of autonomous construction adoption. While the benefits highlight the potential improvements in time saving, improved quality, enhanced safety, cost effectiveness, and reduction in manual labour dependency, the barriers represent the high cost, lack of skilled workforce, resistance to change, technological maturity, and job security concerns.

© UIR Press
e-ISSN: 3110-7737
DOI: 10.25299/ijbs.2026.26441

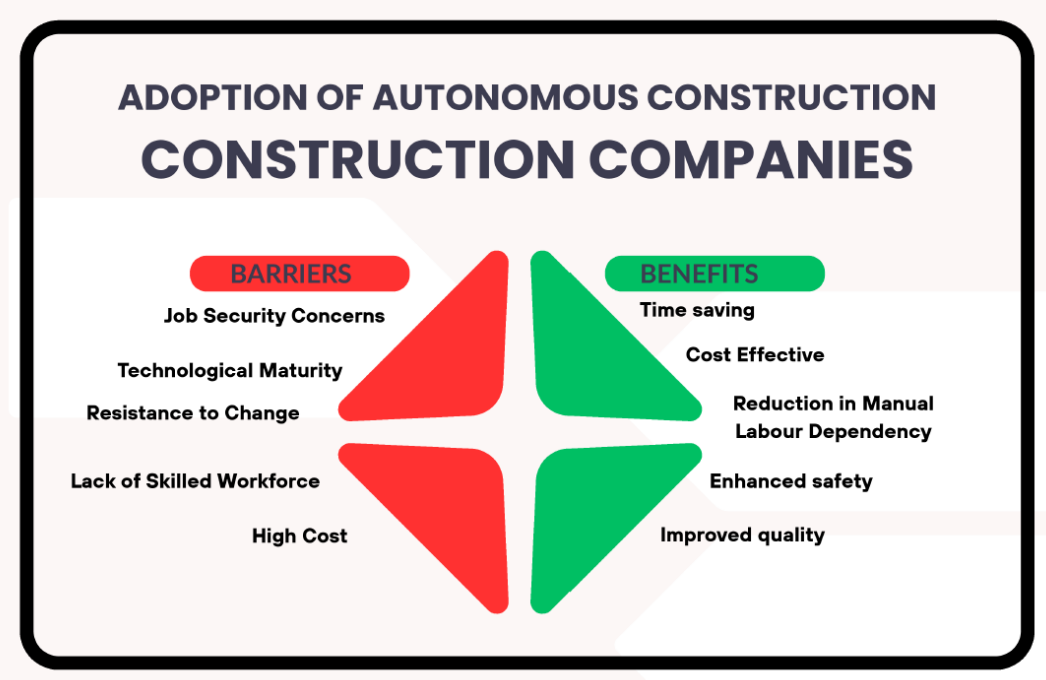

Figure 1
The Adoption of Autonomous Construction: Barriers and Benefits

Aligned with the findings of Frank et al. (2019), the research highlighted that autonomous construction speeds up construction tasks and reduces the likelihood of errors, resulting in more precise outcomes. Despite these clear benefits, the research also uncovered several challenges that hinder the widespread implementation of autonomous technologies. The findings of this research align with those of Balasubramanian et al. (2021) by empirically validating the significance of high initial investment in the Malaysian construction context. This confirmation strengthens prior theoretical findings within emerging economies, highlighting that financial constraints remain a structural barrier across different levels of technological advancement. Such high investment discourages construction companies from investing in autonomous construction, on top of the uncertainty around returns. Hence, this slows the adoption of autonomous construction, leaving construction companies with outdated technology and constraining their ability to achieve long-term sustainability gains.

In addition, these financial issues point to a lack of institutional support, such as government funding and incentives. Although the construction company is willing to innovate, it may not adopt autonomous technology without structured assistance, especially among small and medium-sized enterprises (SMEs). As a result, SMEs are unable to take advantage of new technology and miss out on progress compared to big players. As proposed by Oladimeji et al. (2023), to facilitate the adoption of technological advancement in construction companies, the government must create specialized funding programs to help SMEs. This indicates that government support functions as a moderating factor in the adoption process. Without structured incentives, construction companies may delay adopting this technology despite recognizing its operational benefits.

The successful adoption of autonomous construction requires dedicated testing facilities, which need public resource funding. The result revealed that there are no clear guidelines or rules for autonomous construction since these technologies are not fully developed. Similar to the finding from Abeywickrama et al. (2025), uncertainty in standards causes practitioners to hesitate in adopting safety protocols, integrating compatible systems, or incorporating new technologies into existing workflows. This reflects a gap in technological reliability, where construction companies are reluctant to scale the implementation until operational stability is demonstrated under local project conditions. This uncertainty often results in a cautious approach toward technological adoption. Establishing real-world testing facilities would enable construction companies to practice operating robotic equipment under controlled and simulated conditions, thereby strengthening their technological competencies and operational preparedness. To assist with this barrier, innovation zones operated by government authorities must be available, providing regulatory flexibility for technology developers to perform autonomous construction equipment research. According to Ge et al. (2022), practical demonstrations, pilot projects, and real-world case studies can effectively illustrate how these autonomous technologies can revolutionize construction practices. By providing clear evidence of the benefits, stakeholders can better understand the value of adopting such innovations.

Volume: 1, Issue: 3, 2026

Another barrier to the adoption of autonomous construction highlighted in this research is the lack of collaboration among stakeholders. Collaboration among technology suppliers, academic researchers, and industry leaders enables all participants to share ideas as their autonomous construction adoption progresses. According to Lee and Lim (2021), academic research supports industry by advancing technological knowledge and enabling more effective integration of emerging technologies, which is essential for addressing implementation challenges stemming from weak research–industry collaboration. Besides, early-stage training should be established at universities or institutions that focus on construction automation, AI, and digital construction. As suggested by Li (2024), investing in such education initiatives is critical for developing a future-ready workforce capable of driving innovation and adapting to emerging industry demands. Thus, exposing robots to early training through simulation is crucial for them to cope with difficult situations in construction. Furthermore, having a competent, skilled workforce reduces reliance on imported labour, giving organisations greater flexibility while also contributing to national economic growth and resilience.

Technological maturity was also identified as an area of concern in this research. Using news technology and involving the employee in the implementation process increases the acceptance and effectiveness of autonomous systems. By combining early staff engagement with training programs, a construction company can manage resistance levels and build an able workforce that demonstrates strong confidence in operating autonomous technologies. The goal is to manage both human intervention and automated processes in robotics for construction, to increase job safety and overcome the shortage of experienced workers by handing over difficult jobs to machines. As mentioned by Tortorella et al. (2021), high-tech movement requiring for empowering and committing employees. The implementation of Industry 4.0 requires their participation and engagement, especially in sectors with higher technological intensity, such as the construction industry. Moreover, framing autonomous construction as both a productivity enhancer and an environmental solution could help increase acceptance, as it is directly tolinked of the organization's sustainability.

Conclusion and Implications

This study aimed to understand the factors affecting the adoption of autonomous construction, particularly among contractors in Malaysia. The findings show that autonomous construction offers benefits to the organization, but there are still barriers to its adoption. The adoption of autonomous construction technologies offers significant benefits to the construction industry, particularly in enhancing productivity, quality, and sustainability. This results in time savings, improved quality, enhanced safety, cost-effectiveness, and reduced dependence on manual labour. The results showed that although the organization has exposure to autonomous construction, significant challenges remain that hinder the widespread implementation of autonomous technologies. These barriers are interrelated and

e-ISSN: 3110-7737
DOI: 10.25299/ijbs.2026.26441

further complicated by high costs, a lack of a skilled workforce, resistance to change, technological maturity, and job security concerns. The adoption of this technology in Malaysia is targeted toward aligning with the CIDB's Construction 4.0 Strategic Plan. A lack of necessary funds, skilled employee and resistance to change make it challenging for construction companies to work with autonomous systems, especially among SMEs. The digital transformation of the construction industry will face difficulties if these challenges are not well addressed. The insights gained from this study will assist the stakeholders in developing new strategies and policies and strengthening the industry's long-term sustainability.

Theoretically, this study provides in-depth insights into the benefits and barriers to autonomous construction adoption across the construction industry in Malaysia. The findings suggest that organizational readiness, workforce quality, and support from public institutions contribute to the successful adoption of autonomous construction. The transformation of construction into autonomous construction, leading to productivity, safety, and long-term sustainability expends the current understanding of how digital transformation influences business sustainability in the construction sector. Additionally, the results emphasized that technological advancement should be seen as part of a wider socio-technical system rather than an isolated innovation. This view adds to the theoretical discourse by empirically demonstrating that the success of autonomous construction depends on alignment among technology, human capital, and governance structures.

From a practical view, the successful adoption of autonomous construction implementations relies on an ecosystem comprising infrastructure, human resources, and institutional support. In the absence of such a supporting ecosystem, the automation initiative may remain slow, thus limiting its potential in enhancing operational excellence in the construction industry. Additionally, government participation is important in facilitating autonomous construction adoption through support policies, funding mechanisms, and innovation platforms. Revising education with technological demands from industry will help create a workforce for the future. Raising competency levels in digital, automation, and robotics will decrease reliance on foreign experts while increasing the resilience of local workforces.

Limitation

Despite the above contributions, this study encountered several limitations. The first limitation of the study was its reliance on qualitative data from semi-structured interviews with participants, which yielded useful insights into their opinions, attitudes, and observations. The study focused on Malaysia, so its findings may not be generalizable to other regions. Since the readiness, financial means, and construction regulations can differ widely in Malaysia and abroad, it is challenging to generalize. The lack of quantitative data makes it difficult to fairly assess how much these technologies help and compare them across various construction projects. If results are not measurable, it is difficult for government agencies, investors or construction executives to evaluate expenses, plan for return on investment or make procurement decisions. It would be helpful to expand understanding of construction automation by combining in-depth research findings with statistical information, pilot project evaluations, and studies across different cases to account for real-world experiences.

Generative AI Disclosure

The authors declare that no generative AI tools were used in the preparation of the manuscript.

Ethical Considerations

The ethical integrity was conducted through voluntary participation, informed consent, and all the data was treated confidentially for academic purposes.

Reference

Abbasnejad, B., Soltani, S., Karamoozian, A., & Gu, N. (2024). A systematic literature review on the integration of Industry 4.0 technologies in sustainability improvement of transportation construction projects: state-of-the-art and future directions. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/sasbe-11-2023-0335

Adebayo, Y., Udoh, P., Kamudyariwa, X. B., & Osobajo, O. A. (2025). Artificial intelligence in construction project management: A structured literature review of its evolution in application and future trends. *Digital, 5*(3), 26. https://doi.org/10.3390/digital5030026

Alaloul, W. S., Alzubi, K. M., Malkawi, A. B., Al Salaheen, M., & Musarat, M. A. (2022). Productivity monitoring in building construction projects: a systematic review. *Engineering, Construction and Architectural Management, 29*(7), 2760-2785. https://doi.org/10.1108/ECAM-03-2021-0211

Alnajjar, O., Atencio, E., & Turmo, J. (2025). A Systematic Review of Lean Construction, BIM and Emerging Technologies Integration: Identifying Key Tools. *Buildings, 15*(16), 2884. https://doi.org/10.3390/buildings15162884

Aripin, N. M., Mezhuyev, V., Nawanir, G., Yusuf, M. F., & Haron, N. R. H. M. (2023). Unveiling key drivers of Industry 4.0 adaptation in CKD automotive manufacturing companies: evidence from Asia and South America. *IEEE Access, 11*, 136049-136062. https://doi.org/10.1109/ACCESS.2023.3337426

Asif, M., Naeem, G., & Khalid, M. (2024, 2024-03-01). Digitalization for sustainable buildings: Technologies, applications, potential, and challenges. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2024.141814

Balasubramanian, S., Shukla, V., Islam, N., & Manghat, S. (2021). Construction industry 4.0 and sustainability: an enabling framework. *IEEE Transactions on Engineering Management, 71*, 1-19. https://doi.org/10.1109/TEM.2021.3110427

Basir, E. K. (2025). *AI drives nation's construction industry revolution*. BERNAMA. Retrieved September 7 from

Busetto, L., Wick, W., & Gumbinger, C. (2020). How to use and assess qualitative research methods. *Neurological Research and Practice, 2*. https://doi.org/10.1186/s42466-020-00059-z

Chan, T. K., & Abdul-Aziz, A.-R. (2020). Construction industry development in Malaysia. In *Improving the Performance of Construction Industries for Developing Countries* (pp. 222-239). Routledge.

Creswell, J. W., Klassen, A. C., Plano Clark, V. L., & Smith, K. C. (2011). Best practices for mixed methods research in the health sciences. *National Institutes of Health, 2013*, 541-545.

Dehdasht, G., Ferwati, M. S., Abidin, N. Z., & Oyedeji, M. O. (2022). Trends of construction industry in Malaysia and its emerging challenges. *Journal of Financial Management of Property and Construction, 27*(2), 161-178. https://doi.org/10.1108/JFMPC-08-2020-0054

Delgado, J. M. D., Oyedele, L., Ajayi, A., Akanbi, L., Akinade, O., Bilal, M., & Owolabi, H. (2019). Robotics and automated systems in construction: Understanding industry-specific challenges for adoption. *Journal of building engineering, 26*, 100868. https://doi.org/10.1016/j.jobe.2019.100868

International Journal of Business Sustainability

Volume: 1, Issue: 3, 2026

e-ISSN: 3110-7737
DOI: 10.25299/ijbs.2026.26441

Dhamak, P., Aital, P., & Daftardar, A. (2025). A comprehensive overview of Construction 4.0 technologies and their implementation in the construction industry. *Journal of Science and Technology Policy Management*. https://doi.org/10.1108/JSTPM-09-2023-0162

Farsangi, E. N., Noori, M., Yang, T., Sarhosis, V., Mirjalili, S., & Skibniewski, M. J. (2025). *Digital Transformation in the Construction Industry: Sustainability, Resilience, and Data-Centric Engineering*. Woodhead Publishing.

Fei, W., Opoku, A., Agyekum, K., Oppon, J. A., Ahmed, V., Chen, C., & Lok, K. L. (2021). The critical role of the construction industry in achieving the sustainable development goals (SDGs): Delivering projects for the common good. *Sustainability, 13*(16), 9112. https://doi.org/10.3390/su13169112

Frank, M., Ruvald, R., Johansson, C., Larsson, T., & Larsson, A. (2019). Towards autonomous construction equipment-supporting on-site collaboration between automatons and humans. *International Journal of Product Development, 23*(4), 292-308. https://doi.org/10.1504/IJPD.2019.105496

Hwang, B.-G., Li, Y.-S., Shan, M., & Chua, J.-E. (2020). Prioritizing critical management strategies to improving construction productivity: empirical research in Singapore. *Sustainability, 12*(22), 9349. https://doi.org/10.3390/su12229349

Jaafar, M., Salman, A., Ghazali, F. E. M., Zain, M. Z. M., & Kilau, N. M. (2024). The awareness and adoption level of emerging technologies in Fourth Industrial Revolution (4IR) by contractors in Malaysia. *Ain Shams Engineering Journal, 15*(5), 102710. https://doi.org/10.1016/j.asej.2024.102710

Kim, K., Tiedmann, H. R., & Faust, K. M. (2024). Construction industry changes induced by the COVID-19 pandemic. *Engineering, Construction and Architectural Management*. *32* (7), 4413–4438. https://doi.org/10.1108/ECAM-09-2023-0983

McCutcheon, D. M., & Meredith, J. R. (1993). Conducting case study research in operations management. *Journal of operations management, 11*(3), 239-256. https://doi.org/10.1016/0272-6963(93)90002-7

Melenbrink, N., Werfel, J., & Menges, A. (2020). On-site autonomous construction robots: Towards unsupervised building. *Automation in Construction*. https://doi.org/10.1016/j.autcon.2020.103312

Murguia, D., Soetanto, R., Szczygiel, M., Goodier, C. I., & Kavuri, A. (2026). Construction 4.0 implementation for performance improvement: an innovation management perspective. *Construction Innovation, 26*(3), 843-870. https://doi.org/10.1108/CI-08-2023-0184

Musarat, M. A., Alaloul, W. S., Zainuddin, S. M. B., Qureshi, A. H., & Maqsoom, A. (2024). Digitalization in Malaysian construction industry: Awareness, challenges and opportunities. *Results in Engineering, 21*, 102013. https://doi.org/10.1016/j.rineng.2024.102013

Oti-Sarpong, K., Pärn, E. A., Burgess, G., & Zaki, M. (2022). Transforming the construction sector: An institutional complexity perspective. *Construction Innovation, 22*(2), 361-387. https://doi.org/10.1108/CI-04-2021-0071

Peng, H., Wang, X., Wu, H., & Huang, B. (2025). Human-Computer Interaction Empowers Construction Safety Management: Breaking Through Difficulties to Achieving Innovative Leap. *Buildings*. https://doi.org/10.3390/buildings15050771

Rani, N. I. A., Ismail, S., Mohamed, Z., & Mat Isa, C. M. (2023). Competitiveness framework of local contractors in the Malaysian construction industry towards globalisation and liberalisation. *International Journal of Construction Management, 23*(3), 553-564. https://doi.org/10.1080/15623599.2021.1895485

Sargeant, J. (2012). Qualitative Research Part II: Participants, Analysis, and Quality Assurance. *Journal of graduate medical education, 4 1*, 1-3. https://doi.org/10.4300/JGME-D-11-00307.1

Shafei, H., Rahman, R. A., & Lee, Y. S. (2025). Evaluating construction 4.0 technologies in enhancing safety and health: case study of a national strategic plan. *Journal of Engineering, Design and Technology, 23*(4), 1211-1242. https://doi.org/10.1108/JEDT-08-2023-0330

Staccioli, J., & Virgillito, M. E. (2021). Back to the past: the historical roots of labor-saving automation. *Eurasian Business Review, 11*(1), 27-57. https://doi.org/10.1007/s40821-020-00179-1

Statsenko, L., Samaraweera, A., Bakhshi, J., & Chileshe, N. (2023). Construction 4.0 technologies and applications: A systematic literature review of trends and potential areas for development. *Construction Innovation, 23*(5), 961-993. https://doi.org/10.1108/CI-07-2021-0135

Su, S., Sun, A., Yan, H., Wang, Q., Li, L., & Zhu, J. (2025). Optimization of construction program for economic and environmental sustainability. *Renewable and Sustainable Energy Reviews*. https://doi.org/10.1016/j.rser.2024.115006

Vadukkumchery, A. S., & Myneni, K. K. (2023). Assessment of Impact of Mechanization in Construction Projects in India. *Indian Journal of Science and Technology*. https://doi.org/10.17485/ijst/v16i10.1467

Wong, J. M., Ng, S. T., & Chan, A. P. (2010). Strategic planning for the sustainable development of the construction industry in Hong Kong. *Habitat International, 34*(2), 256-263. https://doi.org/10.1016/j.habitatint.2009.10.002

Yildirim, N., Gultekin, D., Hürses, C., & Akman, A. M. (2025). Exploring national digital transformation and Industry 4.0 policies through text mining: a comparative analysis including the Turkish case. *Journal of Science and Technology Policy Management, 16*(3), 555-590. https://doi.org/10.1108/JSTPM-07-2022-0107

Yin, R. (1994). *Case Study Research: Design and Methods* (2nd ed.). Sage Publications.

Yin, R. K. (2013). Case study research: Design and Methods. *14*(1), 69-71. (Thousand Oaks, CA: SAGE)

Yitmen, I., Almusaed, A., Hussein, M., & Almssad, A. (2025). AI-Driven Digital Twins for Enhancing Indoor Environmental Quality and Energy Efficiency in Smart Building Systems. *Buildings*. https://doi.org/10.3390/buildings15071030

Zhao, S., Wang, Q., Fang, X., Liang, W., Cao, Y., Zhao, C., Li, L., Liu, C., & Wang, K. (2022). Application and development of autonomous robots in concrete construction: Challenges and opportunities. *Drones,* 6(12), 424. https://doi.org/10.3390/drones6120424

Corresponding Author

Norhana Mohd Aripin can be contacted at: norhana87@gmail.com

© UIR Press
e-ISSN: 3110-7737
DOI: 10.25299/ijbs.2026.26441