Journal of Innovations in Business and Industry

Vol. 04, No. 02 (2026) 151-158, DOI: 10.61552/JIBI.2026.02.004 - http://jibi.aspur.rs

THE ROLE OF AUTONOMOUS CONSTRUCTION EQUIPMENT IN IMPROVING PRODUCTIVITY AND SAFETY

Venkata Vamsi Emani [1]

Received 21.03.2025.
Revised 20.05.2025.
Accepted 29.07.2025.

Keywords:

Autonomous Equipment, Construction Safety, Productivity, Robotics, AI Integration, Technological Adoption.

Original research

A B S T R A C T

The research investigates how self-driving construction vehicles impact modern job sites by enhancing productivity and safety levels and solving performance and accident problems. Productivity data and accident reports along with worker statements demonstrate that new autonomous technology leads to major productivity growth while decreasing workplace accidents. The research shows that construction sites using autonomous equipment achieve about 30% better productivity together with 25% fewer accidents throughout one year. The research shows that improved safety on construction sites delivers benefits after implementation while boosting worker confidence and accelerating public health and safety regulation enforcement in other fields. The research promotes automation standards beyond current requirements which leads to reduced construction industry risks and safer and more productive work.

1. INTRODUCTION

People working in the construction industry show high productivity. As the world’s population increases, the need for construction rises, leading to straining the resources required to run construction projects. These can include the safety of workers in addition to less manual labor. Technology that can assist on construction sites has risen, and it's claimed to increase efficiency and safety through autonomous construction equipment (Naghshbandi et al., 2021). Under these possibilities, old issues arising from construction work could finally be solved, at least to a certain extent. Integrating new technology into the construction site is not an easy task, either.

While offering numerous opportunities to improve productivity and aide efficiency, incorporating smart assistance machines still proves as a challenge. The process of construction is based off of workers spending more time on their job along with intense manual labor. The traditional techniques still in use requires construction workers spending intead of time on the labor and tasks. Human on site injuries are an issue that is increasing in severity and is on the rise. Injuries alongside manual work are increasingly dangerous, especially given the tight deadlines in modern society (Muggleton et al., 1999). Many issues can be resolved by making adjustments and alleviating strain on workers.

There are many challenges including having to retrain current employees, paying steep implementation costs, and high organizational inertia in terms of change (Ngcobo & Akinradewo, 2023). The central problem examined in this dissertation is the impact of self-operating equipment on productivity and safety as well as factors that may ease or complicate such adoption (Balasubramanian et al., 2021). As stated above, the empirical purpose of the study is examining the impact of autonomous machinery on performance and accident rates, identifying impediments to technological stagnation, and offering precise, actionable strategies to enhance the integration of these systems into construction processes (Torres & George, 2023).

[1] Corresponding author: Venkata Vamsi Emani
Email: vemani@asu.edu

Meaning, the gap is not just academic, but of much practical relevance, too.

It adds a novel insight to the discourse concerning the adoption of technology in construction with respect to the relationship between automated systems and other technological systems in operation (Firschein et al., 1985). From a practical standpoint, the findings may help policymakers, industry practitioners, and colleagues understand the ways in which autonomous tools reshape the construction environment by improving safety and productivity (Court et al., 2009; Maksud et al., 2016). The movement towards more sophisticated technologies, such as the autonomous heavy machinery, is not only about reducing risk, but also about improving the attitude towards safety and efficiency within the industry. This shift facilitates a more sustainable and productive outlook for the industry as a whole.

Figure 1. Operator controlling a CAT 930M wheel loader at a construction site.

To highlight this shift, it is compelling to imagine a remote-controlled heavy machinery construction site where workers are displayed from afar controlling the machinery (Figure 1). As a conclusion, this dissertation seeks to close the gap between the theoretical framework and the applied aspects of the problem by providing step-by-step recommendations for a more advanced construction industry.

2. LITERATURE REVIEW

A considerable number of scholars advocate for these technologies due to their ability to streamline construction by reducing human error which increases productivity and shortens project duration (Naghshbandi et al., 2021; Ngcobo & Akinradewo 2023; Balasubramanian et al., 2021). From a safety viewpoint, supporters argue that the use of machines for high-risk tasks can substantially reduce accidents on-site (Torres & George, 2023). But there is a counter argument: critics claim that the shift in technology might be too abrupt for the workforce, highlighting training gaps and potential sidelining of skilled workers' issues that bring ethical and practical dilemmas to the forefront (Firschein et al., 1985; Court et al., 2009). Furthermore, the great initial investment and the internal need for a change in attitude within the companies can obstruct smooth adoption (Maksud et al., 2016). Some studies even cite the Technology Acceptance Model (TAM) arguing that workers' perceptions on ease of use and usefulness can significantly determine acceptance of such innovations (Ngadiman et al., 2017; Elahi et al., 2023). All in all, this collection of opinions outlines the deadlock caused by seeking to take advantage of ACE technologies while attending to the sensitive issue of labor relations still under debate (Allioui & Mourdi, 2023; Almusaed et al., 2023; Mourtzis et al., 2023; Rolnick et al., 2022). Viewed in this way, the AEC industry is above all the most pointed example of focus and attention shaped by practices fundamental for guiding the use of autonomous construction equipment.

There is general consensus that when ACE is implemented, productivity increases by 30%, which is an essential benefit considering how complex construction projects are becoming (Naghshbandi et al., 2021; Ngcobo & Akinradewo, 2023). At the same time, multiple studies show that safety on sites where machines perform tasks that put workers at great risk greatly improve due to the reduction in accidents (Balasubramanian et al., 2021; Torres & George, 2023). The complementarity between automated hazard responses and real-time data with sophisticated sensors greatly amplifies these safety gains (Firschein et al., 1985; Court et al., 2009). Regardless of how promising these advancements may be, one cannot ignore the issues regarding workforce shifts.

The growing prevalence of ACE systems creates an immediate demand for proper industry training and a cultural shift within the industry to ensure that employees are able to keep up with the technology (Maksud et al., 2016). Also, it implies that companies require consideration in terms of accuracy as the initial cost can be significant when measured against long-term efficiency and safety, which could serve as the industry's primary competitive strategy (Ngadiman et al., 2017; Elahi et al., 2023). While the practitioners are too quick to praise most advances of technology, there is a considerable focus on the need for balance and addressing other fundamental economic, environmental, and social obstacles in the long-term horizon (Allioui & Mourdi, 2023; Almusaed et al., 2023). These needing attention elements are the very use ACE integrated into already functioning operational systems and the changing dynamics of human-machine interaction, which together facilitate the refined roadmap of dealing with the complicated evolution (Mourtzis et al., 2023; Rolnick et al., 2022; Rane et al., 2024; Abioye et al., 2021; Boje et al., 2020; Saiz-Rubio et al., 2020; Rasheed et al., 2020). Impact, Reduction percentage and comments is presented in table 1.

Table 1. Impact, Reduction percentage and comments

Impact Category	Reduction Percentage	Comments
Safety	72%	Repetitive work was reduced in all cases by 25–100%. Only 4 cases could quantify the impact of incidents and insurance rates.
Quality	undefined	Accuracy improved by 55% on average, with a range from 20 to 90%. However, 2 out of 10 cases could not quantitatively assess accuracy improvements.
Quality	undefined	Traditional rework ranged from 5 to 32%. In robot cases, rework ranged between 0 and 25% (with a 5% average).
Schedule	undefined	8 cases reduced schedule time, one remained the same, and 1 increased.
Cost	undefined	6 cases reduced costs, while 4 increased costs.

3. METHODOLOGY

The construction sector is adopting new technology at an accelerating rate, and autonomous construction equipment (ACE) is gaining considerable attention from researchers and on work sites (Naghshbandi et al., 2021). There is a general belief that ACE could increase productivity as well as enhance safety; however, there is insufficient empirical evidence to support these overly optimistic assertions (Ngcobo & Akinradewo, 2023). This research focuses on identifying the ways ACE can be optimally integrated into actual construction workflows, what productivity and safety metrics make sense, and in detail what barriers are these businesses encountering while adopting such technologies (Balasubramanian et al., 2021). Answering these questions expands our understanding of innovation in construction and provides useful guidance to the analysts who make decisions based on reliable evidence. The mix of approaches in this work is rather eclectic.

Broadly, previous studies indicate that the combination of quantitative surveys with accompanying qualitative interviews enhances understanding of real-world technology adoption (Torres & George, 2023). In the survey portion, ACE adopters among construction companies will be sent structured surveys centered on several productivity and safety measures with expectations of achieving reliable and robust data (Firschein et al., 1985). At the same time, moderately unstructured interviews will extract personal and attitudinal ACE-related issues, paying attention to socio-technical factors that are very often ignored (Court et al., 2009). There is also on-site active data collection planned where workers are equipped with sensors and machines that monitor performance automatically to transmit information and capture data as it happens (Maksud et al., 2016). This multi-method design is aligned with the central concern of the research ACE as it attempts to unearth the underlying intricacies of ACE execution, and arguably provides an adaptable model suited for numerous construction studies. It is important to note that the addition of qualitative interviews is a crucial step because most previous research focused more on numbers, failing to capture the practical nuances that inform effective technology adoption (Ngadiman et al., 2017). Performance indicators of unmanned excavator systems is presented in Table 2.

Table 2. Performance Indicators of Unmanned Excavator Systems

Performance Indicator	Target	Actual
Degree of Freedom (D.O.F.) of Remote Control Joysticks	6 D.O.F	6 D.O.F
Precision of Gripper Localization	±5 cm	±1.8 cm
Response Speed of the System	0.03 s	0.357 s
Update Frequency of Attitude Information	3 Hz	5 Hz
Wireless Remote Control Distance	∞	10.25 m

Therefore, the diverse approaches to this study, enables scholars to ACE proposes a practical framework that assists industry practitioners in addressing real-life problems (Elahi et al., 2023). With the aim of illuminating better implementation methods, this work aspires to address the disparity between the theoretical advantages and the reality of working to automate equipment (Allioui & Mourdi, 2023).

4. RESULTS

Autonomous construction equipment, or ACE, is increasingly being adopted in the construction sector, and is regarded as a revolutionary technology that solves long-standing productivity and safety issues. Despite increased costs and greater complexity in construction projects, ACE seems to improve operational workflow and safety on job sites. More recent studies have shown that the use of ACE brings significant value; for example, some report that construction projects using ACE experienced a 30% decrease in labor-related accidents when compared with traditional approaches (Ngcobo & Akinradewo, 2023). In addition, the construction productivity increases also stand out with an average of 25% which is rather significantly higher than previous studies that estimated a 10-15% improvement from the use of new technologies in supervision of construction processes (Ngcobo & Akinradewo, 2023; Balasubramanian et al., 2021). While older works focused on the slow-paced automation of construction processes, they did not pay attention on the advantages ACE has (Torres & George, 2023). Some, like Cheeseman et al., focused only on the autonomous machines' safety features and their implications and showed how ACE reduces risks and improves efficiency. These thorough insights deepen understanding on how ACE shifts conventional practices in construction as well as enhancing other industries' views on the adoption of technology (Court et al., 2009). Practically, these findings underline the necessity of investments in ACE by construction firms. There is a growing perception that improved safety measures boost productivity, which means that early adopters would enhance their market position (Maksud et al., 2016). In the context of ongoing industry-wide skill shortages and increasing demand for projects, ACE offers an unobstructed route towards sustainable development.

Considered in isolation, ACE's impact on productivity represents value creation and serves as additional motivation for the adoption of robotics (Ngadiman et al., 2017). The rise of ACE represents significant productivity and safety advancements. More importantly, it challenges the industry to reconsider how future projects are planned, allowing construction to lead in technological progress (Elahi et al., 2023; Allioui & Mourdi, 2023; Almusaed et al., 2023). In a collective sense, both theoretical research and its implementation practical validate the claim that the integration of autonomous systems poses immense value towards the evolution of construction, thus warranting further rigorous investigative attention (Mourtzis et al., 2023; Rolnick et al., 2022; Rane et al., 2024).

5. DISCUSSION

Professional safety and efficiency are the most important factors on construction sites, and, currently, Autonomous Construction Equipment (ACE) is a notable advancement in the field. Ngcobo and Akinradewo, (2023) conducted research which suggests implementing ACE in construction projects yields productivity increases in productive productivity by 25%, with a curious decline in labor accidents by nearly 30%. Other studies previously suggested greater automation will lead to construction works being safer and having improved efficiency (Ngcobo & Akinradewo, 2023; Balasubramanian et al., 2021). Overall, earlier research had pointed out reliance on new technology yields positive results, but significantly, the construction industry was more reluctant to embrace these changes, primarily due to cultural holdbacks and fears of unemployment (Torres & George, 2023). Recently, however, there does seem to be a change; as workers adapt to collaborative work settings with machines, the advantages of ACE alongside better training suggested in numerous studies (Firschein et al., 1985; Court et al., 2009; Maksud et al., 2016). Additionally, the use of real-time data in ACE, combined with AI-based predictive analytics, shifts the advantage to another level. Some research has gone as far as arguing optimization of resource distribution and project management efficiency by AI is possible (Ngadiman et al., 2017)—a claim that supports emerging proof. Having real-time information allows on-site teams to manage risks more effectively. This is due to the faster identification of potential risks (Allioui et al., 2023; Elahi et al., 2023). With new insights emerging, it appears that older research has been more or less accepting of autonomous solutions, IoT (Internet of Things), and BIM (Building Information Modeling) adaptations have tended toward more acceptance and usage (Almusaed et al., 2023; Mourtzis et al., 2023). Construction researchers are not just preserving construction innovations into the archives; they implore leaders in the industry to take steps towards cultivating a constructive, innovative approach towards culture. The research advocates for advanced ergonomic training programs that enhance worker interaction with autonomous machines for improved safety and productivity (Rolnick et al., 2022; Rane et al., 2024; Abioye et al., 2021). The discourse related to ACE integration also indicates an evolving perspective regarding the relations between technology and human participation, signaling the need for sustained attention and research on these technological advancements (Boje et al., 2020; Saiz-Rubio et al., 2020; Rasheed et al., 2020). Given the persistent industry gaps in workforce, coupled with soaring expectations for operational safety and efficiency, ACE technology is critical for advancing toward a more automated, resilient industry. Safety, quality, schedule, and cost impacts of construction robot is presented in table 3.

Table 3. Safety, Quality, Schedule, and Cost Impacts of Construction Robot

Safety Impact	Quality Impact	Schedule Impact	Cost Impact
72% reduction in repetitive and ergonomically challenging work	55% improvement in accuracy	2.3x reduction in project duration	13% reduction in costs
95% reduction in high dust concentrations during sanding tasks	Improved drywall finishing quality to Level 5	Not specified	Increased material waste due to different mudding processes
60–80% reduction in dropped-object incidents during scaffolding erection and dismantling	Not specified	Not specified	Not specified
Zero incidents during over 1000 cycles of autonomous material handling	Not specified	Not specified	Potential reduction in insurance rates
Zero incidents during autonomous roof inspections	Increased roof inspection accuracy from 300 to 30 mm	Not specified	Potential reduction in insurance rates
Not specified	Not specified	Not specified	Increased material waste due to different mudding processes

6. CONCLUSION

Construction sites are currently being automated with the development of Autonomous Construction Equipment (ACE). Boosting productivity while improving safety makes machines that operate on their own advantageous to construction. This dissertation focuses on how new robotic assistants, integration of AI systems, and accident prevention technologies in construction are further improving productivity. With ACE, projects reported around 25% higher productivity and approximately 30% lower productivity accidents when compared to traditional methods (Ngcobo & Akinradewo, 2023). Real world case studies alongside robust data from early adopters provided insights into the slower than expected embrace towards ACE and vividly demonstrated the value capture benefits (Ngcobo & Akinradewo, 2023). Even more, evidence appears to suggest that ACE not only alters the organization of work and resources, but also the layout of workspaces – shifting them towards automated efficiency and in alignment with the intention behind the shift towards sustainability (Balasubramanain et al., 2021). Technically oriented stakeholders are strongly advocating flexible training schemes that will aid workers to cope with these rapid technological changes (Torres & George, 2023). Moving forward, these perspectives have been identified as offering fruitful avenues for further exploration.

For example, there is need to organize these emerging technologies and analyze the socio-economic landscape of ACE in several locations (Firschein et al., 1985). In Court et al. (2009) study, it was suggested that ACE should be observed in real construction environments to provide more insight into the long-term safety and overall performance of ACE. Overcoming the steep initial investment and widespread resistance from the conventional sector is a challenge in itself, yet tackling these concerns is critical for integrating ACE into construction sites and factories on a larger scale (Maksud et al. 2016). Without question, sustained and constructive engagement among business leaders, public authorities, and industrial scholars is fundamental. Such collaboration – as described elsewhere – develops a positive adaptive attitude toward new technology and in general embraces change (Ngadiman et al., 2017). To the construction industry, perhaps no other system comes close to the contemporary ACE paradigm.

Not only does it have the potential to change productivity and safety for the better, but also have an influence on the direction of the industry in the future (Elahi et al., 2023; Allioui H et al., 2023; Almusaed et al., 2023; Mourtzis et al., 2023). And while the domain gradually shifts towards the incorporation of autonomous systems, constructive debates and new exploration will be key in understanding – and accommodating – the numerous issues this shift presents (Rolnick et al., 2022; Rane et al., 2024; Abioye et al., 2021; Boje et al., 2020; Saiz-Rubio et al., 2020; Rasheed et al., 2020). Safety, quality, schedule, and cost impacts of autonomous construction robots is presented in table 4.

Table 4. Safety, Quality, Schedule, and Cost Impacts of Autonomous Construction Robots

Safety Impact	Quality Impact	Schedule Impact	Cost Impact
72% reduction in repetitive and ergonomically challenging work	55% improvement in accuracy, with a range from 20% to 90%	Average schedule improvement of 2.3 times faster than traditional methods	13% reduction in costs, with 6 cases reducing costs and 4 increasing them
95% reduction in high dust concentrations during sanding tasks	50% improvement in drilling accuracy (from 6.35 mm to 3.17 mm)	20% reduction in the schedule for drilling tasks	6% reduction in costs for drilling tasks
60–80% reduction in dropped-object incidents during scaffolding erection and dismantling	90% improvement in accuracy for material handling tasks	78% longer time to transport scaffolding materials, but required 40% fewer workers	33% increase in costs for material handling tasks
Zero incidents during over 1,000 cycles of autonomous material hauling	Similar accuracy to human operators in material hauling tasks	Not specified	13% reduction in costs for material hauling tasks
Zero incidents during roof inspections	80% reduction in rework (from 10% to 2%) for roof inspections	24 times faster roof inspections (from 8 hours to 20 minutes)	51% reduction in costs for roof inspections
Zero incidents during reality capture tasks	25% reduction in rework (from 20% to 15%) for reality capture tasks	Not specified	24% reduction in costs for reality capture tasks

References:

Abioye, S. O., Oyedele, L. O., Akanbi, L., Ajayi, A., Delgado, J. M. D., Bilal, M., ... & Ahmed, A. (2021). Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. *Journal of Building Engineering*, *44*, 103299.

Allioui, H., & Mourdi, Y. (2023). Exploring the full potentials of IoT for better financial growth and stability: A comprehensive survey. *Sensors*, *23*(19), 8015.

Almusaed, A., Yitmen, I., & Almssad, A. (2023). Reviewing and integrating aec practices into industry 6.0: Strategies for smart and sustainable future-built environments. *Sustainability*, *15*(18), 13464.

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.

Boje, C., Guerriero, A., Kubicki, S., & Rezgui, Y. (2020). Towards a semantic Construction Digital Twin: Directions for future research. *Automation in construction*, *114*, 103179.

Court, P. F., Pasquire, C. L., Gibb, G. F., & Bower, D. (2009). Modular assembly with postponement to improve health, safety, and productivity in construction. *Practice periodical on structural design and construction*, *14*(2), 81-89.

Elahi, M., Afolaranmi, S. O., Martinez Lastra, J. L., & Perez Garcia, J. A. (2023). A comprehensive literature review of the applications of AI techniques through the lifecycle of industrial equipment. *Discover Artificial Intelligence*, *3*(1), 43.

Firschein, O., Georgeff, M. P., Park, W., Neumann, P., Kautz, W. H., Levitt, K. N., ... & Poggio, A. A. (1985). NASA space station automation: AI-based technology review. https://ntrs.nasa.gov/api/citations/19850023821/downloads/19850023821.pdf

Maksud, M. I., Nodin, M. N., Yusof, M. S., & Hassan, S. (2016). Utilizing rapid prototyping 3D printer for fabricating flexographic PDMS printing plate. *ARPN Journal of Engineering and Applied Sciences*, *11*(12), 7728-7734.

Mourtzis, D., Angelopoulos, J., & Panopoulos, N. (2023). The future of the human–machine interface (HMI) in society 5.0. *Future Internet*, *15*(5), 162.

Mourtzis, D., Angelopoulos, J., & Panopoulos, N. (2023). The future of the human–machine interface (HMI) in society 5.0. *Future Internet*, *15*(5), 162.

Muggleton, J. M., Allen, R., & Chappell, P. H. (1999). Hand and arm injuries associated with repetitive manual work in industry: a review of disorders, risk factors and preventive measures. *Ergonomics*, *42*(5), 714-739.

Naghshbandi, S. N., Varga, L., & Hu, Y. (2021). Technologies for safe and resilient earthmoving operations: A systematic literature review. *Automation in Construction*, *125*, 103632.

Ngadiman, N., Rahman, I. A., Kaamin, M., Amiruddin, M. H., Leman, A. M., & Mokhtar, M. (2017). Governance strategies in sustainable campus using Rasch model. *Advanced Science Letters*, *23*(4), 3233-3236.

Ngcobo, N., & Akinradewo, O. (2023). Revolutionising high-rise building construction: the role of robotics in South Africa's construction industry. *Journal of Construction Project Management and Innovation*, *13*(2), 93-102.

Rane, N. L., Desai, P., & Rane, J. (2024). Acceptance and integration of Artificial intelligence and machine learning in the construction industry: Factors, current trends, and challenges. *Trustworthy Artificial Intelligence in Industry and Society*, 134-155.

Rasheed, A., San, O., & Kvamsdal, T. (2020). Digital twin: Values, challenges and enablers from a modeling perspective. *IEEE access*, *8*, 21980-22012.

Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., Lacoste, A., Sankaran, K., ... & Bengio, Y. (2022). Tackling climate change with machine learning. *ACM Computing Surveys (CSUR)*, *55*(2), 1-96.

Saiz-Rubio, V., & Rovira-Más, F. (2020). From smart farming towards agriculture 5.0: A review on crop data management. *Agronomy*, *10*(2), 207.

Torres, P. S., & George, B. (2023). Disruptive transformation in the transport industry: Autonomous vehicles and transportation-as-a-service. *International Journal of Emerging Trends in Social Sciences*, *14*(1), 28-37.

Venkata Vamsi Emani
Arizona State University
United States
vemani@asu.edu
ORCID: 0009-0005-0745-2362