International Journal of Basic and Applied Sciences, 14 (SI-1) (2025) 433-436

International Journal of Basic and Applied Sciences

Website: www.sciencepubco.com/index.php/IJBAS
https://doi.org/10.14419/j73j3q73
Research paper

Unmanned Ground Vehicles in Smart Construction and Military Applications

Sonali Mondal [1] *, Moti Ranjan Tandi [1], Charpe Prasanjeet Prabhakar [2]

[1] *Assistant Professor, Department of CS & IT, Kalinga University, Raipur, India*
[2] *Department of Electrical and Electronics Engineering, Kalinga University, Raipur, India*
**Corresponding author E-mail: ku.sonalimondal@kalingauniversity.ac.in*

Received: May 2, 2025, Accepted: May 29, 2025, Published: November 1, 2025

Abstract

Autonomous or remotely operated UGVs do the groundwork at distances where human presence at the control station is not required. Robotics with AI and sensor technology enables UGVs to be useful in smart construction and military operations. UGVs do construction work to do automated site inspections and material transport in hazardous environments, thus increasing operational safety and productivity and reducing human risk exposure. Military organizations deploy UGVs across various operations to surveil battle spaces, disarm explosives, and deliver tactical support, which combines increased effectiveness with reduced risk to personnel. Although UGVs have huge potential, they face many technical challenges. UGV technology has three main building blocks, which are navigation precision in rough terrain and energy conservation. Military UGVs have three main ethical issues and challenges with combat autonomy and AI integration into human command. The need for technical innovation, regulatory development, and safety legislation comes from these challenges. This study looks at the existing use of UGVs in military and civilian sectors and will look at both their current limits and underlying capabilities. Continuous innovation, ethical research, and operational testing of the technology are required to get results.

Keywords: *Vehicle; Military Application; UGV; Sensor; Battle Spaces.*

1. Introduction

1.1. Smart construction

The automated construction industry has UGVs to thank for its evolution which has taken manual labor out of dangerous and time-consuming tasks [1]. UGVs in construction industry applications survey sites, map areas, and analyze terrain features for project planning data [8]. They transport materials and reduce physical work requirements thus improving site efficiency [2]. UGVs operate on rough and hazardous terrain where human workers face dangers where there's heavy machinery and unstable ground [13] [10]. These robots work independently to improve project safety reduce errors, and faster construction timelines in smart construction [16].

1.2. Military applications

UGVs are the backbone of modern military operations as they can do dangerous tasks better and get precise results [6]. These platforms do intelligence collection during reconnaissance operations through nonlethal personnel engagement [3]. Military personnel get real-time data through UGV data collection systems which integrate cameras and sensors with communication platforms to explore rough terrain and hostile areas [14]. Bomb disposal operations use UGVs because these vehicles provide a safe implementation of explosive device deactivation in hazardous environments [4].

2. Methodology

2.1. Data collection

This study provides insight into UGV deployments and their real-time impact. The choice of reports and publications was guided by their applicability in unmanned ground vehicles (UGVs) in the construction and military industries. Peer-reviewed journal articles, industry reports of the major manufacturers of robots, and government-published reports of the UGV deployments were used as primary sources. The selection criteria were the recency of the data, the strength of the applied methodologies, and the geographic location of the studies which guaranteed the review of the UGV usage in the world. This research provides the data used in the given research in different company

Copyright © Sonali Mondal et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

reports, articles, study papers, and government publications. This work was dedicated to the actual UGV implementation and the factors that predetermined their success under different working conditions [15].

2.2. A Survey of UGV technologies

In this research, the author discusses the different varieties of unmanned ground vehicles (UGVs) to determine the nature of its use in the military and other construction purposes. The survey consisted of tracked UGVs, wheeled, and legged UGVs that were designed differently to suit various ground conditions and operational needs [7]. The study also investigated such as autonomous navigation and tele-operated systems were considered in the research. Autonomous UGVs are based on powerful AI programs in conjunction with GPS and navigation sensors, whereas remote controlled trucks require the guidance of a human operator [17]. The research used the strengths and weaknesses of each type to determine their performance in the various tasks in the construction and mining industry.

2.3. Challenges

There were several significant issues that UGV deployment and operation had during the survey. The cost of implementing new technologies is high and this is coupled with different maintenance costs and training costs of training the employees to create a significant obstacle in adoption. The requirement of very high-quality hardware and programs is necessary since UGVs need to be operated on an independent and semi-autonomous basis in unpredictable conditions. Natural factors that influence the operation of UGVs comprise harsh weather, terrain-specific factors, as well as electromagnetic interruptions that disrupt systems. Safety was also considered during the evaluation of UGVs, with the concern of safety risks to the human workers as well as the safety risks to the robots that will work within the environment where the UGVs would interact with humans, and the presence of dangerous chemicals at the construction sites and military bases.

2.4. Smart construction and military applications

The military use and smart construction of UGVs have common technological basis, such as autonomous movement and real-time data-gathering features, as well as the necessity of effective AI algorithms. Nevertheless, the working issues in either of the areas differ greatly. The UGVs must perform operations in hazardous conditions and have to deal with human operators in hostile conditions in military operations, and mostly in construction, where they are involved in site mapping, surveying, and handling materials in controlled conditions. Regardless of these disparities, the two disciplines have common issues related to energy efficiency, navigation accuracy, and application of AI to autonomous tasks.

3. UGVs for Smart Construction

3.1. Survey and mapping

A revolutionary shift occurred in surveying and mapping operations in the construction sector with the opportunities of the UGVs combined with the LiDAR (Light Detection and Ranging) equipment, along with the GPS systems [9]. The self-driving robot cars have the potential to address difficult terrain and collect the exact topography data, resulting in the accurate and efficient evaluation of a project site. UGVs mounted with LiDAR sensors produce detailed three-dimensional site maps, which can guide users in the engineering project in the initial planning phase up to the design phase, and monitoring processes. The GPS technology will guarantee reliable geolocation that will lead to an increase in the levels of accuracy of data collected [18]. The system of automated surveying that UGVs execute offers a quicker way of gathering data and less human error, and offers a safer environment and efficacy than a manual survey procedure.

3.2. Material handling

Smart construction is done using UGVs that perform material-handling work and simplify the requirements of human support, and enhance site performance. UGVs will be able to deliver materials such as bricked steel beams and concrete to the sites with their integrated navigation and sensors and payload handling technology [11]. The automated process of material handling of UGVs eliminates the risks of bulky lifting and time-threatening monotonous operations. UGVs are efficient to use in the optimization of material transport routes and guarantee on-time logistics, and minimize delays. The use of UGVs can enhance the efficiency of construction deadline and the construction operations in general, thus leading to project efficiency.

3.3. Challenges in UGV deployment

Besides navigation difficulties, UGVs have a high threat of cybersecurity risks, especially in the military, where they can be vulnerable to hacking or electronic warfare. UGV security research has been emphasized by authors like Zuppelli et al. (2021), who note that effective cybersecurity is necessary to ensure that UGVs do not suffer any interference or malicious attacks. Moreover, the introduction of machine learning algorithms to adjust to the terrain in UGVs as the works of Gholami et al. (2025) show, gives both opportunities and challenges in the reliability and strength of complex environments.

4. UGVs in Military Applications

UAVs have been deployed in the reconnaissance tasks in intelligence gathering and mapping of enemy terrain by the modern army. The self-driving cars have various sensors comprising cameras and communication systems that provide real-time data in the form of high-definition image outputs, temperature picture documentation, and environmental surveillance. UGVs can work around minefields, city war zones, and fortifications, thereby minimizing risks to the on-ground people. Autonomous decision-making about combat situations is one of the ethical issues of miliary UGVs. Since these vehicles can do it without the participation of a human, the question is who is liable in case of a life-and-death decision made by an AI system, like the one that targets a person or combat. Furthermore, the responsibility of AI mistakes, including the inability to identify targets or failure in the operation, is not well-developed. These autonomous systems have legal and ethical implications, which Kostopoulos et al. (2025) discuss and suggest that stringent accountability systems be created to tackle these issues. The ethical theories (utilitarianism, deontology, justice-oriented solutions) offer different points of view on the operation of military UGVs, and the regulations should guarantee clarity and justice in AI decisions.

5. Results

5.1. Performance and efficiency

The system works in complicated conditions with little human input that minimizes errors to obtain quality results. The UGV systems yield the same results throughout a large duration which makes them a necessity in both sectors. According to Pathfinding Systems among Smart Construction technologies report, 24 hours of autonomous operation of the technology reduced the number of people involved by 60%.

Table 1: Efficiency Improvements, Continuous Operation, and Human Involvement Reduction for UGVs in Smart Construction and Military Applications

Sector	Efficiency Improvement	Continuous Operation (Hours)	Human Involvement Reduction (%)
Smart Construction	30% faster data collection	24 hours	60%
Military Applications	25% faster reconnaissance	24 hours	70%

5.2. Cost-effectiveness

The start-up cost of UGVs is high, hence huge savings during their life. By taking on human tasks in high-risk, monotonous, and labor-intensive work, UGVs reduce labor costs. UGVs reduce workplace accidents, which means lower insurance costs and fewer insurance claims. Operational cost savings from using Unmanned Ground Vehicles, plus increased safety and efficiency, mean profitable returns over longer periods. The future savings from UGV automation make the upfront technology cost worth it.

Table 2: Initial Investment, Annual Savings, and Return on Investment (ROI) Period for UGVs in Smart Construction and Military Applications

Sector	Initial Investment ($)	Annual Savings ($)	ROI Period (Years)
Smart Construction	250,000	100,000	3
Military Applications	300,000	120,000	2.5

5.3. Autonomy and control

Modern UGVs can operate autonomously in dynamic environments through their AI algorithms. Construction teams deploy UGVs to do automated tasks in areas where human operators don't need or can't have primary control. UGVs are deployed in military missions to do reconnaissance and bomb disposal, and eliminate human interaction. UGVs need human control for missions that involve complex problems or critical safety situations. AI can do independent system operations, and human control is required for mission success and total safety in certain situations. The chart shows the Sector's Autonomous Operation rate and percentage requiring Remote Oversight and Operational Safety risk reduction.

Table 3: Autonomy, Remote Oversight Requirements, and Operational Safety for UGVs in Smart Construction and Military Applications

Sector	Autonomous Operation (%)	Remote Oversight Required (%)	Operational Safety (Risk Reduction %)
Smart Construction	85%	15%	50%
Military Applications	80%	20%	65%

6. Conclusion

Unmanned Ground Vehicles (UGVs) bring big benefits to smart construction and military operations through increased operational efficiency, reduced hazardous task execution, and safer working conditions. By doing automated surveying and material handling, and inspections, UGVs free human construction workers and protect workers from danger zones. The military uses UGVs to do reconnaissance while eliminating bombs and supporting supply operations for front-line soldiers through tough terrain. UGV technology can solve many operational problems, but its wide adoption is hindered by high upfront cost, machine limitations, and a lack of regulations to govern its deployment. A lot is happening with autonomous systems and AI-powered UGVs, but human observers need to oversee high-risk operations for now. The deployment of UGVs is limited by environmental factors such as difficult terrain and harsh climates. Current operations in all industries must be reviewed before UGVs can be integrated into their workflows. Automated ground vehicles have a bright future because continuous improvements in AI robotics and sensor technology will continue to advance. Because of ongoing R&D, UGVs will break through current limitations, become more affordable, reliable, and functional, and expand their applications in multiple sectors.

Future research on UGVs should focus on optimizing energy efficiency, particularly for military applications where UGVs often operate in remote areas with limited energy resources. Further studies should also investigate the development of regulatory frameworks for safe human-UGV interactions, especially in construction zones where human workers are near autonomous systems. Additionally, there is a need for research into the scalability of UGV technology in large-scale infrastructure projects and the ethical considerations of using autonomous systems in high-risk military operations.

References

[1] Jung, S. (2025). MILP-based cost and time-competitive vehicle routing problem for last-mile delivery service using a swarm of UAVs and UGVs. *Journal of Air Transport Management*, *124*, 102736. https://doi.org/10.1016/j.jairtraman.2024.102736.

[2] Saidova, K., Ashurova, M., Asqarov, N., Kamalova, S., Radjapova, N., Zakirova, F., Mamadalieva, T., Karimova, N., &Zokirov, K. (2024). Developing framework for role of mobile app in promoting aquatic education and conservation awareness among general people. *International Journal of Aquatic Research and Environmental Studies, 4*(S1), 58-63. https://doi.org/10.70102/IJARES/V4S1/10.

[3] Shao, Y., Xu, H., Liu, L., Dong, W., Shan, P., Guo, J., & Xu, W. (2025). An energy-efficient distributed computation offloading algorithm for ground-air cooperative networks. *Vehicular Communications,* 100875. https://doi.org/10.1016/j.vehcom.2025.100875.

[4] Zuppelli, M., Carrega, A., & Repetto, M. (2021). An Effective and Efficient Approach to Improve Visibility Over Network Communications. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, 12*(4), 89-108.

[5] Kostopoulos, N., Stamatiou, Y. C., Halkiopoulos, C., & Antonopoulou, H. (2025). Blockchain Applications in the Military Domain: A Systematic Review. *Technologies, 13*(1), 23. https://doi.org/10.3390/technologies13010023.

[6] Boopathi, P., & Gomathi, P. (2019). Scientometric Analysis of Library and Information Science Articles During the Year 2008-2017 Using Web of Science. *Indian Journal of Information Sources and Services, 9*(S1), 12–15. https://doi.org/10.51983/ijiss.2019.9.S1.574.

[7] Frasier, M. A., Coleman, J., Maguire, J., Trslić, P., Dooly, G., & Toal, D. (2025). Autonomous Forklifts: State of the Art—Exploring Perception, Scanning Technologies and Functional Systems—A Comprehensive Review. *Electronics, 14*(1), 153. https://doi.org/10.3390/electronics14010153.

[8] Kumar, S. (2024). Exploring Pharmaist Challenges with Pubmed Studies with Relational Prescribing. *Clinical Journal for Medicine,Health and Pharmacy, 2*(3), 11-20.

[9] Asadi, K., Suresh, A. K., Ender, A., Gotad, S., Maniyar, S., Anand, S., ... & Wu, T. (2020). An integrated UGV-UAV system for construction site data collection. *Automation in Construction, 112,* 103068. https://doi.org/10.1016/j.autcon.2019.103068.

[10] Sowmiya, E., Chandrasekaran, V., & Sathya, T. (2017). Sensor node failure detection using round trip delay in wireless sensor network. International Journal of Communication and Computer Technologies, 5(1), 12-16.

[11] Abbadi, D., & Lachkar, A. (2025). The Cybersecurity Risks Threatening Drones: Innovative Solutions in the Digital Age. https://doi.org/10.20944/preprints202501.0694.v1.

[12] Kuljanin, J., &Zivojinović, T. (2025). 10 Drone Technology. Intelligent and Sustainable Engineering Systems for Industry 4.0 and Beyond, 180. https://doi.org/10.1201/9781003511298-10.

[13] Gholami, A., & Ramirez-Serrano, A. (2025). Terrain Traversability via Sensed Data for Robots Operating Inside Heterogeneous, Highly Unstructured Spaces. *Sensors, 25*(2), 439. https://doi.org/10.3390/s25020439.

[14] Abbadi, D., & Lachkar, A. (2025). The Cybersecurity Risks Threatening Drones: Innovative Solutions in the Digital Age. https://doi.org/10.20944/preprints202501.0694.v1.

[15] Gargano, I. E., von Ellenrieder, K. D., & Vivolo, M. (2025). A Survey of Trajectory Planning Algorithms for Off-Road Uncrewed Ground Vehicles. In International Conference on Modelling and Simulation for Autonomous Systems (pp. 120-148). *Springer, Cham.* https://doi.org/10.1007/978-3-031-71397-2_8.

[16] Bosco, N. J. (2016). Farmers' Perceptions on Maize Varieties in Rwanda: A Case Study of Smallholder Farmers in Rwimbogo Sector in Gatsibo District. *International Academic Journal of Innovative Research, 3*(2), 1–8.

[17] Munasinghe, I., Perera, A., & Deo, R. C. (2024). A comprehensive review of uav-ugv collaboration: Advancements and challenges. *Journal of Sensor and Actuator Networks, 13*(6), 81. https://doi.org/10.3390/jsan13060081.

[18] Vellingiri, A., Kokila, R., Nisha, P., Kumar, M., Chinnusamy, S., & Boopathi, S. (2025). Harnessing GPS, Sensors, and Drones to Minimize Environmental Impact: Precision Agriculture. In Designing Sustainable Internet of Things Solutions for Smart Industries (pp. 77-108). *IGI Global.* https://doi.org/10.4018/979-8-3693-5498-8.ch004.

[19] Kavitha, M. (2025). Hybrid AI-mathematical modeling approach for predictive maintenance in rotating machinery systems. Journal of Applied Mathematical Models in Engineering, 1(1), 1–8. https://doi.org/10.17051/JAMME/01.01.01.

[20] Faizal, A., Huda, N., & Ismail, A. B. (2025). Why Most Leaders Fail at Technology Integration: New Research Reveals Success Patterns. National Journal of Quality, Innovation, and Business Excellence, 2(1), 55-65.

[21] Novak, P., & Jurić, M. (2025). AR in Tourism Creates Authentic Guest Experiences: Real Cases from Top Hotels. Journal of Tourism, Culture, and Management Studies, 2(1), 38-46.

[22] LUBIS, A. (2025). The Effect of Budget Participation Relationship and Organizational Mechanization on Regional Tax Performance Mediated by The Budget Slack in Indonesia. Quality-Access to Success, 26(206). https://doi.org/10.47750/QAS/26.206.26.

[23] Nayak, A., & Salabi, L. (2025). Low-latency communication protocol design for ultra-reliable IoT applications in smart cities. Progress in Electronics and Communication Engineering, 3(1), 29–37.*

[24] Hyunjae, L., & Okunki, L. (2025). Optimization of brushless DC motor controllers for energy-efficient motion control systems. National Journal of Electric Drives and Control Systems, 1(2), 1–8.

[25] Tandi, M. R., & Punam, S. R. (2025). Thermal-aware power converter design using AI-based cooling optimization for renewable applications. Transactions on Power Electronics and Renewable Energy Systems, 1(2), 17–25.

[26] Gomez, A., & Santhakumar, B. (2025). Investigating Channel Modeling and Propagation Characteristics for High-Frequency Links in Deep-Sea Applications. National Journal of Antennas and Propagation, 7(2), 76-85. https://doi.org/10.31838/NJAP/07.02.13.

[27] Punam, S. R., & Patel, P. (2023). Biodiversity Corridors in Fragmented Forest Landscapes: Enhancing Connectivity for Climate-Resilient Ecosystems. National Journal of Forest Sustainability and Climate Change, 1(1), 17-24.

[28] Alvarez, R. (2023). Integrating Precision Livestock Farming Technologies for Early Detection of Zoonotic Disease Outbreaks. National Journal of Animal Health and Sustainable Livestock, 1(1), 17-24.

[29] Kavitha, M., & Abdullah, D. (2023). Nutritional Transitions and the Rise of Non-Communicable Diseases in Urban Africa. *National Journal of Food Security and Nutritional Innovation*, *1*(1), 17-24.

[30] Li, Q. H., & Muralidharan, J. (2025). 3D IC integration with through-silicon vias for high-density computing applications: Design and thermal considerations. Journal of Integrated VLSI, Embedded and Computing Technologies, 2(3), 89–96.

[31] Mukti, I. Z., & Shimada, T. (2025). Multi-objective optimization of EV smart charging infrastructure using hybrid AI and IoT frameworks. National Journal of Intelligent Power Systems and Technology, 1(4), 17–24.

[32] Alkilany, A., & Mlein, M. (2025). Socio-technical analysis of renewable microgrids for energy access in developing regions. National Journal of Renewable Energy Systems and Innovation, 1(3), 33–41.

[33] Kim, Y., & Chowdhury, U. (2025). Electrochemical–thermal coupled modeling of high-capacity lithium-sulfur batteries for grid applications. Transactions on Energy Storage Systems and Innovation, 1(2), 18–25.