

Can Construction Robotics Build More Sustainably??

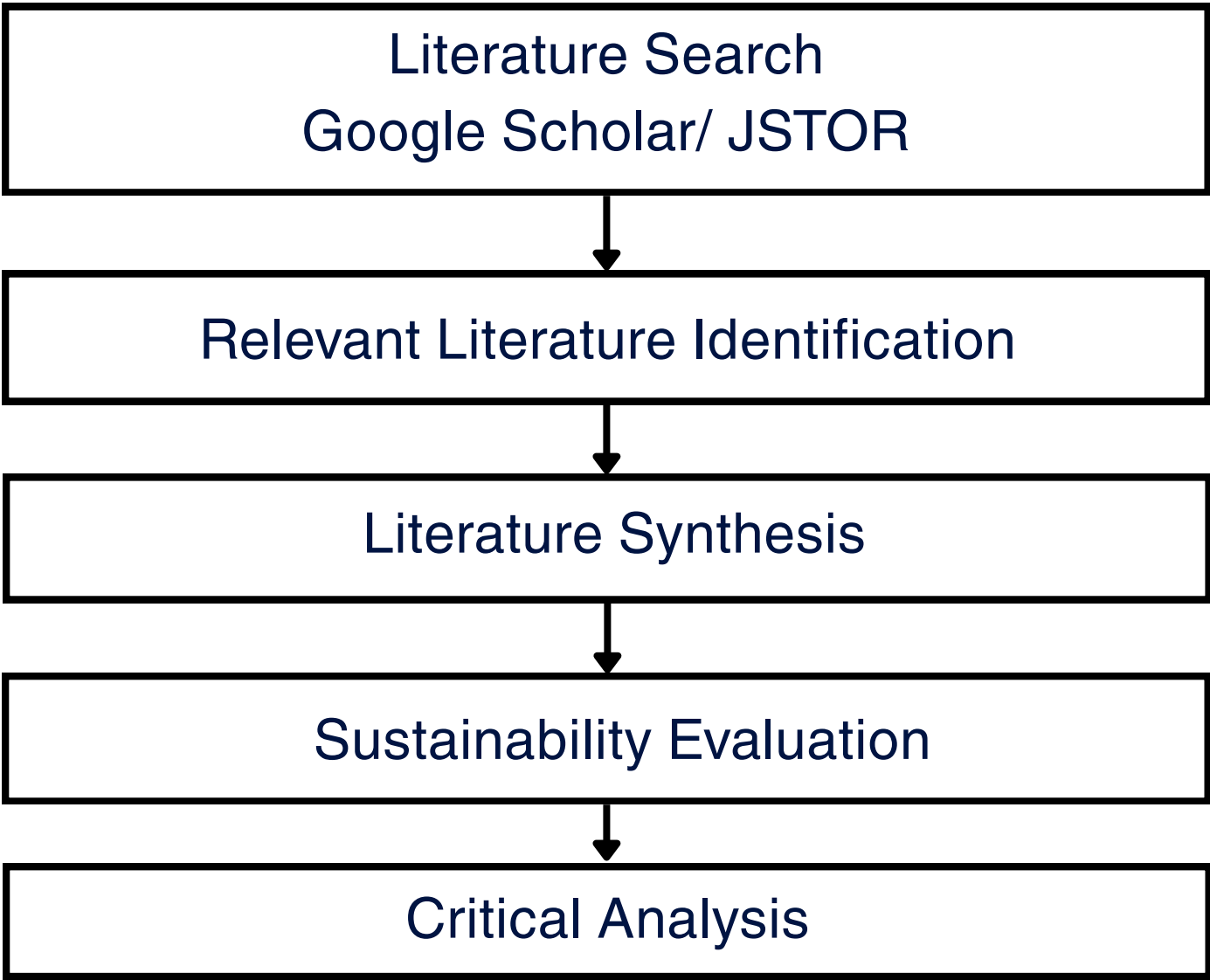
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Introduction

- Construction has substantial environmental impacts, accounting for approximately 40% of global energy consumption and 25% of CO₂ emissions [1].
- Construction robotics can improve precision, efficiency, safety, and resource use, but may introduce energy and life-cycle impacts.
- This review examines the potential of robotics to support more sustainable construction

Research Question: How can construction robotics reduce environmental impact and improve sustainable building practices?

Methodology



Robotic additive manufacturing in construction. Image: COBOD International [15]

Key Findings

Robotic Technology	Sustainability Benefits	Challenges/ Trade-offs	Optimization / Recommendations	Key Evidence
Robotic Additive Manufacturing (3D Printing)	Reduced material waste; improved material efficiency and precision; potential use of recycled and locally sourced materials; potential reductions in labour/material requirements [2,3,4]	High printing energy demand; embodied impacts of materials [3,5]	Lower-impact/recycled materials; renewable/lower-carbon energy; printing/process optimization [6]	48% lower life-cycle carbon emissions than conventional housing in one LCA, despite higher printing-stage emissions [7]
On-Site Construction Robots	Reduced rework; faster construction; improved precision; reduced hazardous worker exposure; potential energy/emission reductions [8,9]	High initial and maintenance costs; site variability and setup requirements; challenges operating in harsh/unstructured [8] construction environments.	Energy-efficient operation; task/path optimization; integration with digital monitoring and planning	Automated bricklaying reduced modeled construction time from ~20 to 10 days and produced ~\$12,000 estimated cost savings. Other automated applications showed environmental reductions, although outcomes varied considerably by application. [10]
Drones (UAVs)	Efficient surveying; early risk/defect detection; reduced hazardous inspections; environmental and thermal monitoring [11,12]	Environmental benefits are primarily indirect; Battery waste, charging emissions, and energy-intensive/ [13] low-recyclability materials.	BIM/AI integration for automated analysis, real-time monitoring, and coordination with ground robots/sensor networks [14]	Sustainability contribution primarily comes from improving monitoring and inspection, rather than directly altering the construction process.

Life-cycle impacts

Manufacturing → Transportation → Operation → Maintenance → End-of-life

Discussion

- Life-Cycle Considerations:** Operational energy alone does not determine sustainability; whole-life impacts should be considered.
- Context-Dependent Sustainability:** Environmental performance depends on energy source, materials, application, and implementation.
- Application-Specific Contributions:** AM improves material efficiency, on-site robots improve process efficiency, and UAVs support monitoring.
- Future Technological Integration:** Construction 4.0 and HRC may improve robotic coordination, monitoring, adaptability, and optimization.

Construction robotics can reduce environmental impacts, but its sustainability depends on how and where it is implemented.

Conclusion

- Construction robotics can support sustainability through material and process efficiency, reduced waste, improved safety, and monitoring.
- Sustainability is context-dependent and should consider energy, materials, application, and life-cycle impacts.
- Future research: Explore how Construction 4.0 technologies and HRC can improve the sustainability and implementation of construction robotics.

References

[1] J. Hong, G. Shen, Y. Feng, W. Lau, and C. Mao, "Greenhouse gas emissions during the construction phase of a building: a case study in China," *Science Direct*, <https://doi.org/10.1016/j.jclepro.2014.11.023>

[2] S. Kokare, J. P. Oliveira, and R. Godina, "Life cycle assessment of additive manufacturing processes: A review Author links open overlay panel," *Science Direct*, <https://doi.org/10.1016/j.jmsy.2023.05.007>

[3] H. Hegab, N. Khanna, N. Monib, and A. Salem, "Design for sustainable additive manufacturing: A review - sciencedirect," *Science Direct*, <https://www.sciencedirect.com/science/article/abs/pii/S2214993723000118>

[4] Oberti, I., & Plantamura, F. (2015). Is 3D printed house sustainable?. In *Proceedings of International Conference CISBAT 2015 Future Buildings and Districts Sustainability from Nano to Urban Scale* (pp. 173-178). LESO-PB, EPFL.

[5] Z. Y. Liu, C. Li, X. Y. Fang, and Y. B. Guo, "Energy Consumption in Additive Manufacturing of Metal Parts," *Science Direct*, <https://doi.org/10.1016/j.promfg.2018.07.104>

[6] M. Khosravani and A. Haghighi, "Large-Scale Automated Additive Construction: Overview, Robotic Solutions, Sustainability, and Future Prospect," *MDPI*, <https://doi.org/10.3390/su14159782>

[7] A. Monghayedi, J. Mahachi, R. Lediga, T. Mosiea, and E. Phalafala, "Revolutionizing affordable housing in Africa: A comprehensive technical and sustainability study of 3D-printing technology," *Science Direct*, <https://doi.org/10.1016/j.scs.2024.105329>

[8] R. Dindorf and P. Wos, "Challenges of robotic technology in Sustainable Construction Practice," *MDPI*, <https://doi.org/10.3390/su16135500>

[9] Z. Dakhli and Z. Lafhaj, "Robotic mechanical design for brick-laying automation," *Taylor & Francis*, <https://doi.org/10.1080/23311916.2017.1361600>

[10] S. Mazzetto, H. H. Hosamo, and M. E. Al-Atroush, "How programmable construction can shape the future of sustainable building in Italy," *MDPI*, <https://doi.org/10.3390/su17051839>

[11] K. AL-Dosari, Z. Hunaiti, and W. Balachandran, "Systematic review on civilian drones in safety and security applications," *MDPI*, <https://doi.org/10.3390/drones7030210>

[12] Gallacher, D. (2016). Drone applications for environmental management in urban spaces: A review. *International Journal of Sustainable Land Use and Urban Planning*, 3(4), 1-14.

[13] A. V. 1, H. N. 3, and K. K. 1, "Materials and energy-centric life cycle assessment for drones: A review," *MDPI*, <https://doi.org/10.3390/jcs9040169>

[14] S. A., K. M. H., N. Ramanna, and B. G. B., "Emerging trends in remote sensing and geospatial technologies for construction industry: A comprehensive review," *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, <https://doi.org/10.5194/isprs-annals-X-5-W2-2025-643-2025>

[15] "Projects: Cobod international," COBOD, <https://cobod.com/projects-cobod-3/>