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Robotics adoption: barriers and lessons from other industries

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Manchester Centre for Robotics and AI

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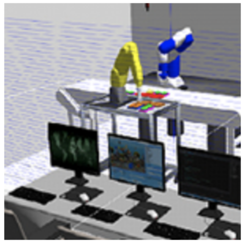
Our Key Research Themes

100+
Researchers across the University

30+
State-of-the-art robots

Platform design, mechatronics and control

Design of new sensing and actuator technologies, the development of novel robot platforms, and research on control methods. The work also focuses on bio-inspired solutions to mechatronics and control, e.g. with the design of biomimetic sensors, actuators and robot platforms and with swarm intelligence approaches for distributed control.



Verification, security and trust

Design of novel formal techniques, software engineering and AI methodologies for verification in autonomous systems, cybersecurity methods for distributed software architectures, and the wider issues for trustworthy autonomous systems.

Human-robot interaction and cognitive robotics

Research issues in human-robot interaction and collaboration. This includes novel approaches to joint action and control, telerobotics, intention reading, language and communication, trust, human-robot teamwork and explainable AI. This theme includes work on the use of cognitive- and brain-inspired approaches to robot control, learning and interaction.

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Our Key Research Themes

<£30m
Research funding since 2017

4
Robotics labs

AI, machine learning and data

Development and application of novel AI and learning-based methods to robotics and autonomous systems. This also includes work on ML for vision. It also covers research on data science and machine learning methods for multimodal robot sensing and for data integrating robots within distributed IoT and ambient intelligence environments.

Ethics and society

Research in ethics and human-centred robotics issues, for the understanding of the impact of the use of robots and autonomous systems with individuals and society (e.g. loneliness), and the considerations of privacy and acceptability of RAS systems. In addition, this theme focuses on robot ethics, i.e. the use of formal methods and tools for ethical machines and the development of robot ethics standards.

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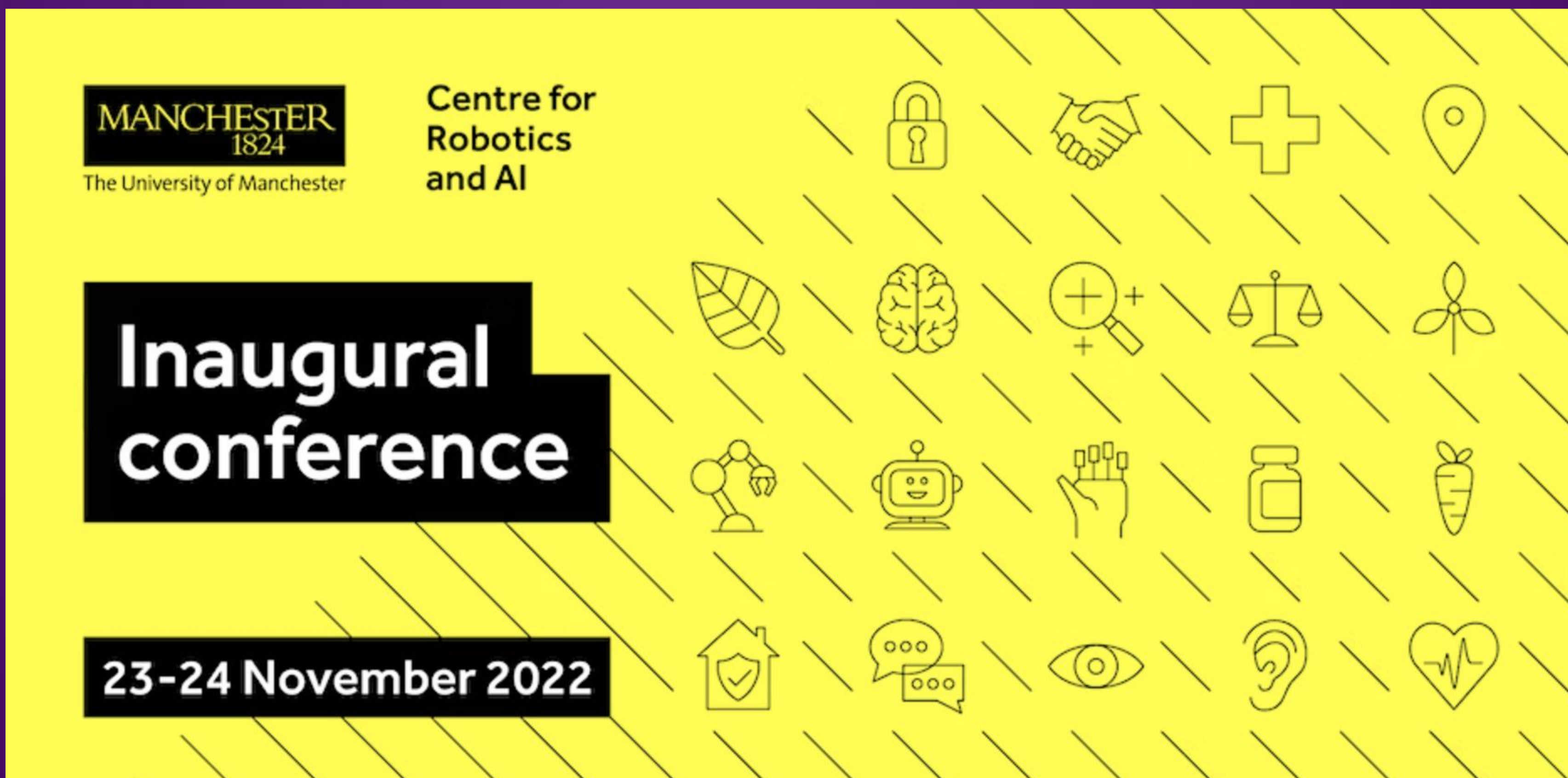
- Information - www.robotics.manchester.ac.uk/
- Connect - RAI@manchester.ac.uk
- Register - https://bit.ly/3fsmL0t



Recent relevant research

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Review

Recent advancements of robotics in construction

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ABSTRACT

In the past two decades, robotics in construction (RiC) has become an interdisciplinary research field that integrates a large number of urgent technologies (e.g., additive manufacturing, deep learning, building information modelling (BIM)), resulting in the related literature being both fragmented and vast. This paper has explored the advances in RiC in the past two decades using a mixed quantitative-qualitative review method. Initially, 940 related articles (170 journal articles and 770 conference papers) were identified by keyword-searching in Scopus and then fed into a bibliometric analysis to build science maps. Following this, a qualitative discussion highlights recent achievements in RiC across three dimensions: tasks, algorithms, and collaborations. Moreover, four future research directions are proposed: 1) in-depth integration of BIM and robotics; 2) near-site robotic fabrication; 3) deep reinforcement learning for flexible environment adaption; and 4) high-level robot-to-robot collaboration. The contributions of this research are twofold: 1) identifying the latest research topics and trends concerning robotic technologies in construction; and 2) providing in-depth insights into the future direction of RiC. The findings from this research can serve both academia and industry in terms of promoting robotic algorithms, hardware, and applications in construction industry.

1. Introduction

The construction industry is one of the most important industrial sectors in North America, contributing 958.8 billion dollars of the United States' gross domestic product in 2021 [1]. Despite this, the construction industry is suffering from labor shortages, high safety risks, and low automation worldwide [2]. Robotics has emerged as a revolutionary technology in the construction industry with the potential to improve productivity and occupational safety [3]. The Robot Institute of America defines a robot as "a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks" [4]. A rapidly expanding literature field of robotics in construction (RiC) has made proposals covering construction equipment with robotic features (e.g., robotic excavators), using robots from other industrial sectors for construction purposes (e.g., drones), and robots customized for the construction industry (e.g., façade cleaning robots). However, adopting robotics in the construction industry still facing many challenges due to the unique characteristics of the construction process. Especially when compared with the manufacturing industry (where robotics has been highly adopted and its influence is the driving force for the adoption of robotics in the construction industry), the construction process has a lower level of standardization and controlled working environment [5].

Today, RiC has become a highly cross-disciplinary research field that integrates robotics with many urgent technologies including additive manufacturing, building information modelling (BIM), and deep learning. As a consequence, the RiC scientific literatures is vast, diverse, and fragmented. Questions associated with RiC that still remain largely unanswered include the following: 1) what are the latest research topics and trends in RiC? and 2) what are the future directions for applying robotic technologies in the construction industry? To answer these research questions and provide in-depth insights into the development of RiC, a comprehensive and up-to-date review is needed. In recent years, several review studies [6–10] have been offered in the field of RiC. For example, David et al. [9] have reviewed robotic inspection systems in the built environment and Pan et al. [10] have reviewed the state-of-the-art construction robot adoption from the perspective of building contractors. However, the existing overview studies are based on manual reviews and are therefore prone to be subjective or even

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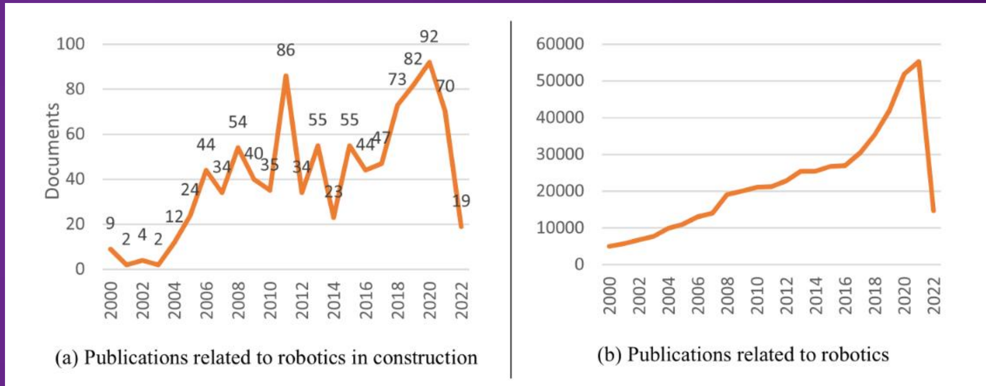

Fig. 2. Number of published studies from 2000-2022: (a) on the topic of robotics in construction, (b) on the topic of robotics

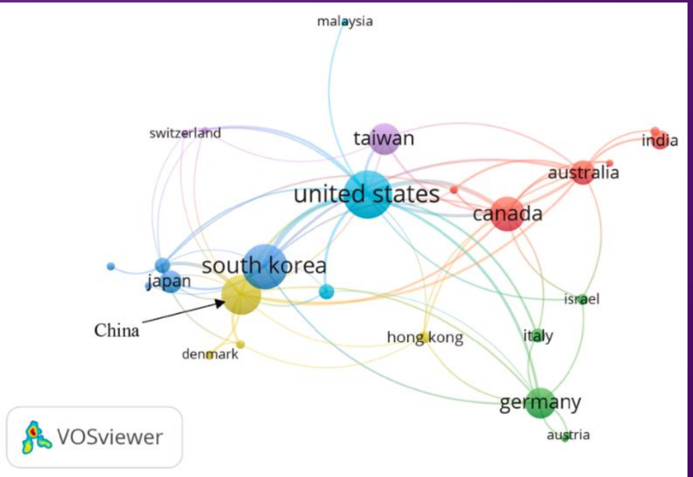

Fig. 5. Co-authorship network in the RiC research domain.

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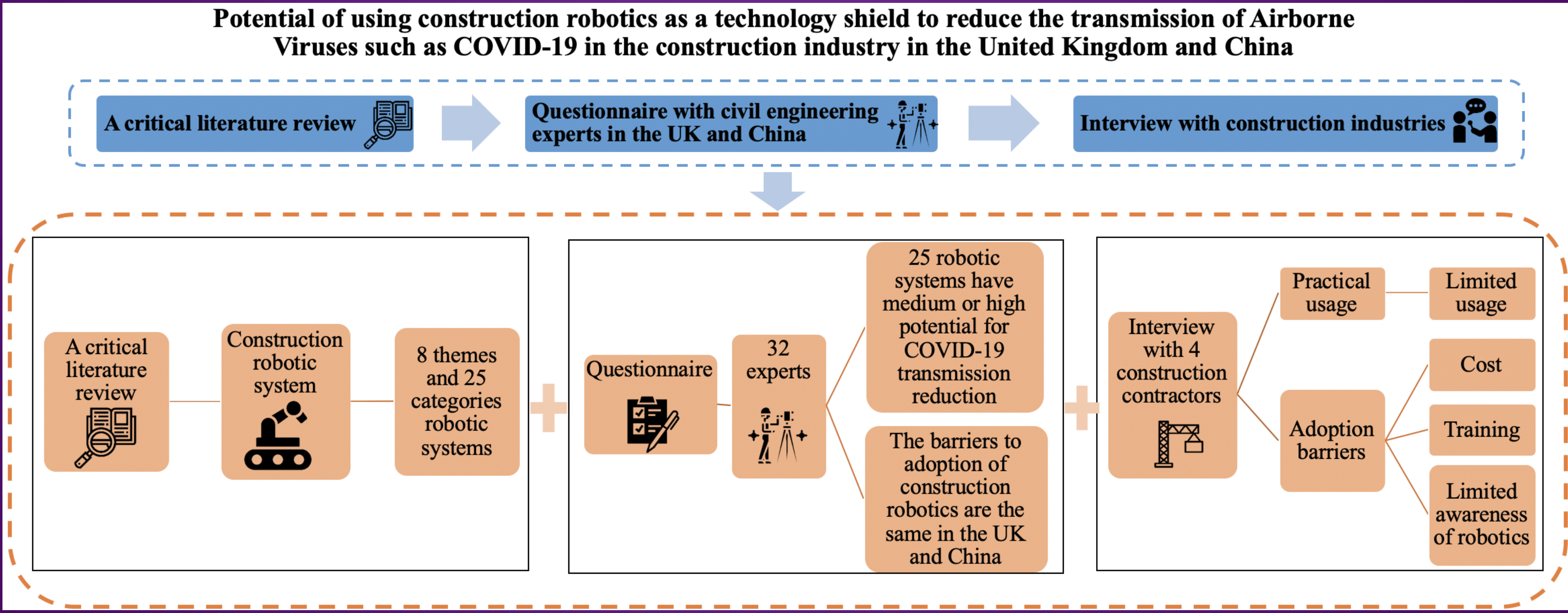
Our Teams research



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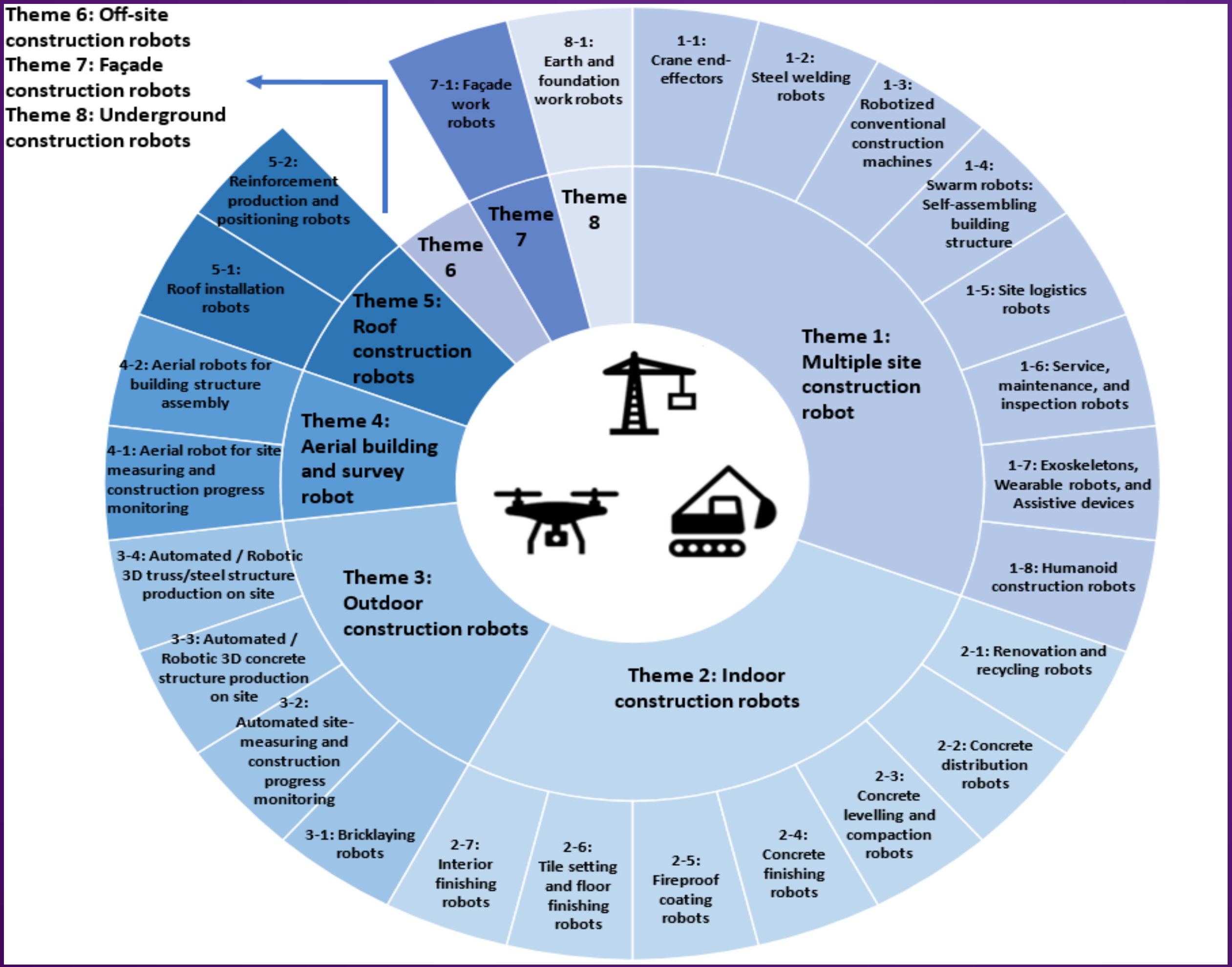
Classification of Construction Robotic Technology



Inner ring - 8 themes
Outer ring - 25 categories

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Classification of Construction Robotic Technology

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Construction Robotics Summary

- We identified 23 commercialised systems
- An important technology to increase productivity [1]
- Experts are willing to adopt it
- No differences in implementation barriers between UK and China (P>0.05)
- Adoption rates in the UK and China are low <1% [1-3]

[1] R.D. Atkinson, Which Nations Really Lead in Industrial Robot Adoption?, Information Technology & Innovation Foundation (2018).
[2] D. Herr, M. Godel, R. Perkins, L. Pate, T. Hall, The economic impact of robotics & autonomous systems across UK sectors, (2020).
[3] L. Changzhou Haigou Construction Technology Co. Construction 4.0: Is the development of construction robots an opportunity or a challenge? 2022

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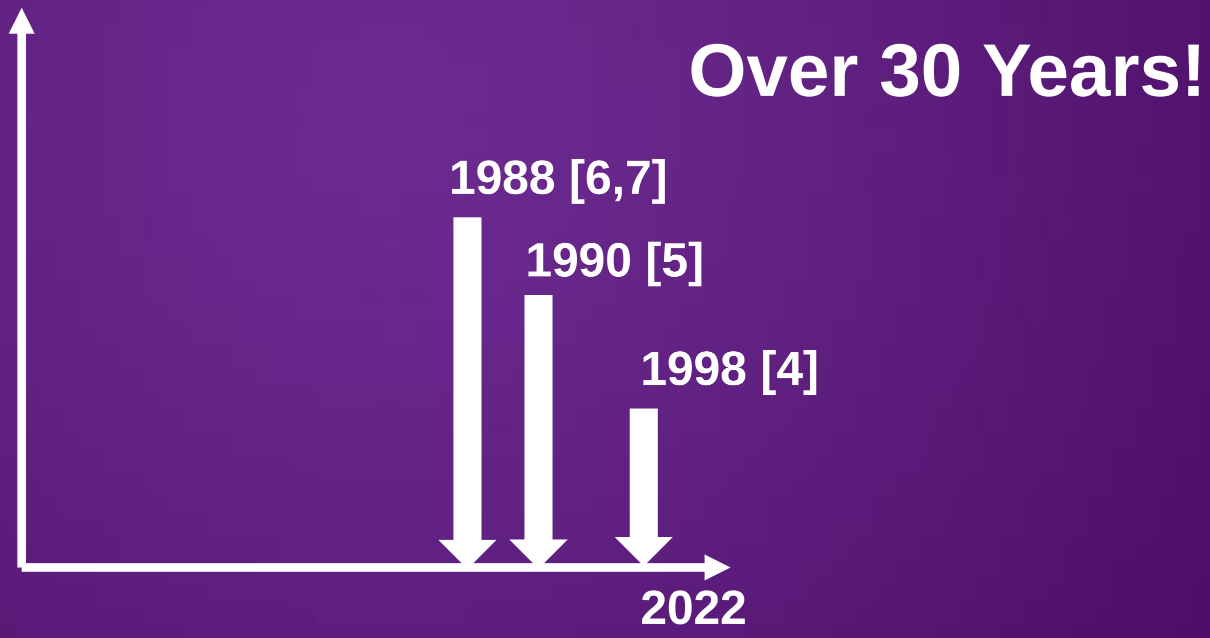
How long have we known about barriers preventing adoption of construction robotics?



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[5] J.S. Russell, M.J. Skibniewski, An ergonomic analysis framework for construction tasks, Construction Management and Economics 8 (3) (1990) 329-338.

[6] M. Skibniewski, C. Hendrickson, Analysis of Robotic Surface Finishing Work on Construction Site, Journal of Construction Engineering and Management 114 (1) (1988) 53-68.

[7] J. Skibniewski Miroslaw, Framework for Decision-Making on Implementing Robotics in Construction, Journal of Computing in Civil Engineering 2 (2) (1988) 188-201.

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Barrier - High Initial Capital Costs

- High capital cost, limited UK financial support [8]
- High implementation costs and low availability [9,10]
- Higher cost robotic technology faces greater barriers [11,12]
- lower cost robotics, greater acceptance and adoption [13,14], e.g. Exoskeletons

[8] F. Bademosi, R.R.A. Issa, Factors Influencing Adoption and Integration of Construction Robotics and Automation Technology in the US, Journal of Construction Engineering and Management 147 (8) (2021) 04021075.
[9] J.M. Davila Delgado, L. Oyedele, A. Ajayi, L. Akanbi, O. Akinade, M. Bilal, H. Owolabi, Robotics and automated systems in construction: Understanding industry-specific challenges for adoption, Journal of Building Engineering 26 (2019) 100868.
[10] R. Bogue, What are the prospects for robots in the construction industry?, The Industrial Robot 45 (1) (2018) 1-6.
[11] Q. Chen, B. García de Soto, B.T. Adey, Construction automation: Research areas, industry concerns and suggestions for advancement, Automation in Construction 94 (2018) 22-38.
[12] P.S. Mistri, H.A. Rathod, Remedies over barriers of automation and robotics for construction industry, Int. J. Adv. Res. Eng. Sci. Manage (2015) 1-4.
[13] R.D. Atkinson, Which Nations Really Lead in Industrial Robot Adoption?, Information Technology & Innovation Foundation (2018).

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High Initial Capital Costs - Lessons from other Industries

- Manufacturing companies in South Korea receive tax credits for investment in new equipment
- This has helped South Korea become the largest adopter of robotics in industry
- In 2017, there were 710 robots per 10,000 workers [13]

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High Initial Capital Costs - Lessons from other Industries

- Tax treatment of capital expenditures in the UK is less generous
- Dampens robotic investments and adoption [14]
- Providing tax credits or reducing taxation could be another solution

[14] B. Dellot, F. Wallace-Stephens, What's Stopping UK Businesses from Adopting AI & Robotics?, Medium, September 18 (2017).

High Initial Capital Costs - Lessons from other Industries

- Factories of the Future contractual Public-Private Partnership launched by European Commission to increase the new technologies and system development [15,16]
- Led to 983 technology innovations by 2017 [17]

[15] N.C.Y. Yeo, H. Pepin, S.S. Yang, Revolutionizing Technology Adoption for the Remanufacturing Industry, Procedia CIRP 61 (2017) 17-21.
[16] K. Ridgway, C.W. Clegg, D. Williams, P. Hourd, M. Robinson, L. Bolton, K. Cichomska, J. Baldwin, The factory of the future, Government Office for Science, Evidence Paper 29 (2013).
[17] E.F.o.t.F.R.A. (EFFRA), Progress Monitoring Report for 2017, Factories of the Future: Public Private Partnership, 2017, pp. 1-2.

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Barrier - Workforce skills gap

- A Skill shortage is a common barrier for the rapid adoption of new technology [18]
- Training the workforce to operate more complex robotic systems requires extra time and cost
- Robots that require less training or experienced operators may gain higher acceptance and adoption

[18] D. Boothby, A. Dufour, J. Tang, Technology adoption, training and productivity performance, Research Policy 39 (5) (2010) 650-661.

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Workforce skills gap - Lessons from other Industries

- Lack of technology awareness causes a skills shortage [19]
- More advanced technology adoption causes a larger skills gap and shortage [20]
- Training is the common way to address the workforce skills gap due to its low cost [18]

[19] D. Palka, J. Brodny, K. Stecuła, Modern means of production and the staff awareness of the technical in the plant of the mining industry, CBU International Conference Proceedings, Vol. 5, 2017, pp. 1190-1194.
[20] D. Sabourin, Skill shortages and advanced technology adoption, Citeseer, 2001.

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Workforce skills gap - Lessons from other Industries

- Training can also transfer stakeholders’ attitudes to adopting new technology and increase the productivity effect more than 50% [18]
- Hence, a mix of industries and governments’ actions are needed to address the workforce skills gap during new technology adoption.

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Barrier - Limited awareness of new technologies

- Our questionnaire showed limited awareness of new technologies correlates with low adoption
- Industry find it difficult to get information on new technology
- Specifically cost and installation time, developments and trends

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Barrier - Limited awareness of new technologies

- Mudan et al in 2020, highlighted the lack of awareness of new technology [21]

- Assessment and selection are still barriers preventing adoption [21]

[21] M. Wang, C.C. Wang, S. Sepasgozar, S. Zlatanova, A Systematic Review of Digital Technology Adoption in Off-Site Construction: Current Status and Future Direction towards Industry 4.0, Buildings 10 (11) (2020) 204.

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Limited awareness of new technologies - Lessons from other Industries -

- The main strategy for increasing stakeholders' awareness of technology should be to increase knowledge in the construction sector [22]
- Roberts et al [22] in 2021 highlighted that unlike academia, stakeholders in industry have fewer opportunities to participate in seminars and conferences

[22] R. Roberts, R. Flin, D. Millar, L. Corradi, Psychological factors influencing technology adoption: A case study from the oil and gas industry, Technovation 102 (2021) 102219.

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Limited awareness of new technologies - Lessons from other Industries

- Robotic suppliers and the industry as a collective could provide support for increasing stakeholders' awareness.
- Current events of UK and Chinese construction industry associations focus on careers, skills training and industry development rather than introducing new technologies, e.g. Build UK [23]
- If these associations could focus more on new technologies this would drive stakeholder awareness

[23] B. UK. BUILD UK: Leading the Construction Industry 2022 [cited 2022 28th July]. Available from: https://builduk.org/.

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Barrier - Unclear economic benefit

- Robotics in manufacturing demonstrates increased output with adoption [24]
- However the benefit to construction is less clear [25,26]
- Unclear economic benefits pose a barrier for industry to adopt and realise the benefit of construction robotics

[24] J. Mayer, Robots and industrialization: what policies for inclusive growth, Friedrich Ebert Stiftung New York, 2018.
[25] T. Bock, The future of construction automation: Technological disruption and the upcoming ubiquity of robotics, Automation in Construction 59 (2015) 113-121.
[26] R. Mahbub, An investigation into the barriers to the implementation of automation and robotics technologies in the construction industry, Queensland University of Technology, 2008.

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Department for Business, Energy & Industrial Strategy

Unclear economic benefit - Lessons from other Industries

- The potential economic benefits of robotic adoption is not straightforward [2], we could determine that they are directly reflected in productivity [27-29]
- According to the UK BEIS *2021*, by increasing productivity, the estimated cost can be reduced by up to 10% for off-site prefabrication tasks [30]

[27] R. Sparrow, M. Howard, Robots in agriculture: prospects, impacts, ethics, and policy, Precision Agriculture 22 (3) (2021) 818-833.
[28] M. Kamarul Bahrin, et al. INDUSTRY 4.0: A REVIEW ON INDUSTRIAL AUTOMATION AND ROBOTIC, Jurnal Teknologi 78 (6-13) (2016).
[29] G. Graetz, G. Michaels, Robots at Work, The Review of Economics and Statistics 100 (5) (2018) 753-768.
[30] E.I.S. Dept for Business, Robotics and autonomous systems: the economic impact across UK sectors, 2021, in: E.I.S. Department for Business (Ed.), 2021.

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Unclear economic benefit - Lessons from other Industries

- The report highlights that if the potential construction robotic adoption rate is achieved (38%), the Gross Value Add (GVA) could reach £10.6 billion by 2035, more than 100 times higher than in 2018 [30]
- Despite the unclear economic benefit of robotics adoption in the construction sector, it is difficult to be addressed by government policy

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Unclear economic benefit - Lessons from other Industries

- Policy makers in the UK and China could help by funding robotic and automation systems, technology innovation or providing skills training to motivate adoption.

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Unclear economic benefit - Lessons from other Industries

- Although the UK and Chinese governments have published some policy to support the technology adoption, [31-32], there still is a long way to achieve high adoption rates.

[31] U. Government, Construction 2025: strategy, in: E.I.S. Department for Business (Ed.), 2013.
[32] X. Song. Understanding the new five-year development plan for the robotics industry in China 2022 [cited 2022 13th June]. Available from: https://ifr.org/post/understanding-the-new-five-year-development-plan-for-the-robotics-industry-in-china.

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Thanks for Listening