

Bricklayers' perspectives on human-robot collaboration (HRC) in on-site masonry construction: opportunities, challenges, and considerations

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Abstract

Purpose – The Australian construction sector is experiencing historically low productivity rates, labour shortages and increased building costs. In bricklaying, highly automated industrial robotic solutions have not alleviated these challenges. Recent advances raise the opportunity for less costly, modular and safer collaborative robots (cobots) extended through augmented reality (AR). This study aims to understand bricklayers' perspectives on working with cobots and AR; identify the opportunities and challenges for cobot integration on-site; and identify key considerations for on-site human-robot collaboration (HRC).

Design/methodology/approach – This study draws upon seven face-to-face semi-structured interviews with Australian bricklayers, including cobot users and non-users. A codebook-informed reflexive thematic analysis (RTA) resulted in three key themes.

Findings – The findings reveal a vital need for human-centred HRC workflows tailored to residential bricklaying. Theme 1 identifies HRC workflows as an enabler to address labour shortages and low productivity, increase workforce diversity and ultimately preserve the profession's longevity. Theme 2 suggests HRC workflows must overcome site integration, safety and usability challenges. Theme 3 addresses design considerations for successful on-site cobot deployment. Complementary AR enhances collaboration by leveraging human capabilities combined with machine assistance.

Originality/value – Aligning the findings with the technology acceptance model (TAM), this study uncovers bricklayer perceptions and attitudes towards working with cobots and AR devices on-site. It outlines the challenges bricklayers' encounter with an existing assistive robot system and key considerations for HRC workflows. Future research will focus on collaborating with bricklayers to design human-centred HRC workflows to improve adoption in the architecture, engineering and construction (AEC) sector.

Keywords Human-robot collaboration (HRC), Bricklaying, Augmented reality (AR), Cobot, Construction robotics, Architectural robotics, Digitalisation, Masonry construction

Paper type Research paper



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1. Introduction

Australia is facing a housing crisis; there are not enough affordable homes being constructed to meet a growing population, and the industry has a diminishing labour and skilled workforce. We know that advanced technologies, including the use of robotics and augmented reality (AR), can help to address these challenges, however, we also know that, similar to other sectors, the industry is reluctant and slow to adopt new technologies. Working in partnership with Brickworks; a local brick manufacturer, this program of research aims to address adoption barriers by developing a demonstrator project, where a bricklayer and a collaborative robot can construct a brick wall together efficiently.

This article presents the first phase of the project, where we strive to understand the challenges faced by the industry, the nuances of what bricklayers do on-site and what is considered as opportunities or difficulties in working with a collaborative robot (cobot) to do manual tasks. The research question we address in this article is:

RQ1. What are the opportunities, challenges and considerations for collaborative robots and augmented reality adoption in the bricklaying workflow of masonry construction?

This initial phase of the research sets the foundations for the development of a human-centred human-robot collaborative workflow for masonry construction.

The construction industry makes a significant contribution to the Australian economy, accounting for 9% of Australia's gross domestic product (GDP) and generating AUD 360 billion in revenue annually (Regona *et al.*, 2022). Construction uses 1.35 million workers, with an exit rate of 8% and a replenishment rate of 4% (Master Builders Australia, 2024). According to Master Builders Queensland, the peak industry association for Queensland's building and construction sector, without timely improvements, the industry will not meet future demand, due to these workforce shortages combined with minimal productivity growth of only 1% over the past two decades (Master Builders Queensland, 2024).

These challenges disproportionately affect the bricklaying sector, which has the largest structural skills gap of all Australian building trades and is in critical shortage (HIA, 2024). At the same time, housing has become increasingly unaffordable due to supply shortages in the face of increased demand (Productivity Commission, 2025). In 2023, 100,000 additional people called Queensland home, but only 35,000 new homes were constructed, far short of the 78,000 required. From a national perspective, the Australian government has set a target for 1.2 million homes to be built from 2024 to 2029, or approximately 240,000 per year. However, by mid-2024, only 176,000 homes were built (Productivity Commission, 2025). Given the sector's challenges, it is understandable that current trends indicate a decline in the use of brick as a building material in residential home construction. Brick veneer remains the most used wall material for new housing construction nationally, accounting for 36.8%, but is down from 55% in 2016 (Commonwealth Scientific and Industrial Research Organisation (CSIRO), 2025).

Productivity and labour force challenges present an opportunity for the construction sector, particularly bricklaying, to adopt digital technologies and processes to be more efficient. Robotics, automation and AR technology have transformed the labour-intensive sectors of manufacturing, agriculture and logistics. Similarly, academic studies and industry applications outline the benefits of the use of robots in construction. For instance, robots can reduce rework and project duration (Oke *et al.*, 2025), carry out strenuous and repetitive tasks (Liang *et al.*, 2021) and help mitigate safety risks (Ikuabe *et al.*, 2023; Perera *et al.*, 2025). Nevertheless, despite decades of robot integration efforts, the construction sector lags far behind other sectors in its adoption efforts (Productivity Commission, 2025; Soltani *et al.*, 2023).

According to [Delgado et al. \(2019\)](#), many factors contribute to low adoption, including client and contractor side economics, technical and work-culture issues and limited business cases. Moreover, unlike the manufacturing sector, where robots tend to perform repetitive tasks such as welding and painting in controlled environments, robots in the construction sector must contend with dynamic and unstructured work sites ([Tomori et al., 2024](#)). This phenomenon, termed “robots in the wild” ([Sabanovic et al., 2006](#)), suggests directed research efforts similar to this study, which target the specific domain of bricklaying construction.

The unstructured nature of the construction site and the nuanced workflows in constructing brick walls introduce barriers for highly automated robotic systems; this is where advances in safer and less costly cobots and complementary AR technologies hold promise. To ensure clarity, the term “bricklayer” is used throughout this paper to refer to tradespeople engaged in both bricklaying and broader masonry tasks, including work with bricks and concrete masonry units (CMUs).

Unlike using industrial robots, bricklayers can directly interact with cobots to assemble walls, with the cobot handling repetitive, laborious and precise tasks. Conversely, bricklayers can focus on dextrous craft-based aspects and adjust and oversee cobot operation in response to challenges ([Burden et al., 2022](#)). This interaction between humans and cobots is referred to as human–robot collaboration (HRC) and can be further enhanced by AR.

AR technologies, such as the Microsoft HoloLens 2, a head-mounted device, can help synergise the valuable tacit and contextual problem-solving skills of bricklayers with the utility of robots. Studies demonstrate AR technology helping teams of bricklayers to construct complex wall designs on-site, guided solely by virtual 3D information overlayed on their physical space ([Fologram, 2022](#)), and allowing them to interact with cobot systems to construct designs that would not be otherwise feasible using either traditional 2D drawings or automated robotic approaches alone ([Franze et al., 2023](#); [Mitterberger et al., 2020](#)).

Despite advances in robot and AR technology, cobots remain underutilised in the bricklaying sector ([Reinhardt et al., 2020](#)). Knowledge gaps persist regarding the on-site integration of cobots, their usability and how bricklaying professionals perceive them. There is also a limited understanding of what HRC workflows entail for effective on-site brick wall assembly. This study addresses these gaps through real-world observations and interviews with expert bricklayers and site managers. Study findings will inform the development of AR-enabled HRC workflows that accelerate build times and reduce building costs, thereby directly contributing to solutions to the Australian housing crisis.

2. The evolution of robotics in bricklaying

2.1 Early automation attempts

One of the oldest and widely used building materials, brick is expected to be in demand for the foreseeable future in Australian cities. Its unique properties make it ideal for constructing durable and visually appealing walls, particularly in challenging environments such as coastal areas prone to salt corrosion, strong winds and variations in moisture. Brick’s density makes it inherently durable, meaning houses can better withstand climatic extremes, floods and bushfires. Brick offers excellent fire resistance, being non-combustible and typically remains structurally sound even after fire events. Bricks offer insulation advantages that can improve thermal efficiency, reduce home heating and cooling needs and also decrease the amount of noise pollution occupants experience ([Jonnala et al., 2024](#)).

Despite the advantages of brick construction, it has always posed several challenges for bricklayers, involving high physical dexterity and strenuous effort, which can lead to musculoskeletal disorders ([Gao et al., 2025](#)). Bricklaying also involves a high degree of craft

and expertise. For example, numerous aspects of bricklaying require tacit knowledge, such as evaluating mortar consistency, applying mortar at the correct thickness, firmly seating bricks on mortar beds and ensuring correct brick orientation and position.

There have been many historical attempts to automate brick wall construction, spanning back as early as 1875 (Ruttico *et al.*, 2024). These early automation efforts often used track-based mechanisms that set down a layer of mortar and placed bricks at predefined intervals. A similar approach is exemplified by the 1967 “Motor Mason”, built in Essex, UK, touted by its creators as laying bricks five to ten times faster than bricklayers and being the answer to the skilled labour shortages and housing crisis of that era (Potter, 2021). However, these early attempts could not navigate corners, adapt to different mortar layup approaches, sense their environment, or address highly variable site conditions or material inconsistencies, all contributing factors that led to their limited commercial success (Potter, 2021).

2.2 1980s to mid-2000s

In the 1980s and 1990s, research initiatives focused on using robotic arms, given their improved information processing capabilities and six degrees of freedom as opposed to linear systems. Examples include the solid material assembly system (SMAS) by Kodama *et al.* (1988), a prototype robotic masonry system by Altobelli *et al.* (1993) and the ROCCO system by Andres *et al.* (1994). These research efforts, although using sophisticated sensing and control systems, did not progress past the prototype stage. Bonwetsch (2012) contends that the research during this period, which focused primarily on economic factors and highly automated systems, was unsuccessful, as they could not adapt to dynamic real-world building sites.

Research efforts into robotic masonry were reinvigorated in the mid-2000s and continue to this day through advances in digital design techniques afforded by parametric computer-aided design (CAD), Building Information Modelling (BIM) and computational design software, along with enhanced sensing, control and guidance systems allowing assembly of highly complex brickwork designs. Notably, the work of NCCR (Gramazio Kohler Research, 2024) and the 2006 project, Winery Gantenbein, demonstrated the ability of robotic production systems to translate complex digital brick façade designs into efficient large-scale brickwork. Since then, academic interest in robotic bricklaying has continued with extensive research programs at ETH Queensland University of Technology Zurich, the Institute of Computational Design (ICD Stuttgart) and the Institute of Advanced Architecture Catalunya (IAAC, Barcelona).

2.3 Recent commercial developments

Industry’s interest in robotics has also grown with several commercial systems in advanced prototype stages, such as the automatic bricklaying robot (ABLR) from Construction Automation (Construction Automation, 2024) and Brick Bot by Platform.AS (Platform AS, 2022). Alongside these, commercial robotic applications in masonry construction include the Australia-based Hadrian X by Fastbrick Robotics, which uses a telescopic robotic arm with bricks fed by a conveyor system mounted on a large truck. Hadrian X converts CAD and BIM into automated construction and excels at detached housing but has deployment challenges in dense urban environments given its scale (Ambrosino *et al.*, 2023).

Since 2015 and up until recently, the U.S. company Construction Robotics has been operating a track-mounted and enclosed robot arm system named the semi-autonomous mason (SAM 100). The SAM 100 unit consists of a robotic arm, gripper, conveyor, and concrete pump. It can lay approximately 2,000–3,000 bricks per hour, achieving close to the 4,000 bricks that a human bricklayer can lay in an hour (Madsen, 2020). The device

incorporates a propane generator that provides power and pneumatics, as well as sensors for measuring critical distances and angles. The robot arm picks up and applies mortar to each brick, while a human operator smooths the mortar before the arm places the brick on the wall (Madsen, 2020). While the SAM 100 appears to be highly precise and efficient on long straight runs, its purported high unit cost and long set-up times (Madsen, 2020) may have hampered its long-term success, as it appears to be discontinued by Construction Robotics.

2.4 The MULE ML 150 system

A primary challenge lies in developing systems that can adapt to the diverse conditions, activities and work sequences inherent to construction sites, enabling direct human collaboration rather than operation behind a protective barrier. In this vein, Construction Robotics produces the material unit lift enhancer (MULE) ML 150, an assistive robotic system or a cobot, pictured in Plate 1 and is also the primary device used by four participants in this study. Being collaborative, the assistive MULE system offers a glimpse into the contextual factors currently encountered by bricklayers in on-site HRC. Construction Robotics also produces a newer, compact MULE MZ 100 system with a rechargeable battery.

MULE is an assistive robotic system designed to assist bricklayers in lifting and placing CMUs. Pictured in Plate 1, the MULE is a modular cobot consisting of a pivoting 3.65-metre arm that sits atop a 3-metre-high mast, a power pack with a compressor and a power connection. Suspended from the arm are the controller box and gripper that bricklayers use to lift material units of up to 68 Kilos.

A key benefit of MULE lies in its collaborative nature, which sees bricklayers providing critical guidance, while the cobot manages heavy lifting. The gripper controller is responsible for evaluating and responding to bricklayers’ instructions through a two-button handle, where users lock and release CMU blocks. Through this interface, users adjust



Plate 1. A bricklayer guides a CMU into position using the MULE system. The MULE’s arm pivots as the bricklayer aligns the CMU on the retaining wall
Source: Armstrong Bricklaying. Used with permission

gripper functions and lift speed. Onboard safety features slow device movements if a load constraint is exceeded.

There is also a range of gripper attachments to suit different material types. As illustrated in [Plate 2](#), operators secure the gripper to an object, such as a CMU, and the MULE then lifts



Plate 2. A close-up view of the bricklayer positioning the CMU in place as the MULE suspended gripper and controller hold it

Source: Armstrong Bricklaying. Used with permission

the CMU, rendering it practically weightless for movement and placement into a wall position ([Smart Lifting for Construction and Masonry - Construction Robotics, 2018](#)).

2.5 Challenges of on-site cobot adoption

Many of the research and commercial projects discussed have centred on using automated large-scale industrial robots or cobots. While these contributions provide a solid base, the use of robotics in bricklaying remains limited. As a result, many unanswered questions remain on how robots are perceived, used and integrated on-site.

Site integration: From existing robot integration attempts, we can ascertain that smaller cobots are better suited for bricklaying sites, as they are more compact, safer and less expensive. To be effective, safety and a smaller footprint are vital for operating cobots on uneven terrain, manoeuvring around numerous obstacles and negotiating between site personnel from varying professions and different subcontracting teams ([Tomori et al., 2024](#)). In addition, there is a need to address issues related to on-site brick feeding systems, spatial operation and managing messy materials like mortar ([Song et al., 2023](#)). Cobots' relatively lower cost, reduces adoption barriers for smaller construction companies, but there is a need to evaluate the trade-offs and impacts of lower payloads and speeds over manual labour or larger industrial systems ([IFR International Federation of Robotics, 2024](#); [Loy et al., 2024](#)).

User perception towards cobots: Another factor that influences whether bricklayers successfully adopt HRC is users' having appropriate levels of trust in the systems ([Liang et al., 2021](#)). While some studies have explored technical performance and safety, limited literature has directly engaged practitioners, such as bricklayers and construction managers, to understand their lived experiences, attitudes and expectations on robot use. Therefore, uncertainty remains around whether bricklayers will accept cobots, particularly due to the industry's historical reliance on manual labour and possible perceived threats to livelihoods ([Walzer et al., 2022](#)).

Usability: Industrial robot systems have limitations, including their expert programming interfaces, large size and heavy weight ([Wu et al., 2024](#)). Cobots offer greater flexibility to be placed on mobile platforms, transported around the site and conduct a range of tasks. A further advantage is their ability to manipulate objects near humans, acting as a co-worker rather than a highly specialised, single-function machine. These collaborative abilities are enabled by their sophisticated sensing abilities and built-in safety mechanisms ([Colgate et al., 1996](#)). As [Reinhardt et al. \(2020\)](#) and [Burden et al. \(2022\)](#) contend, cobots offer advantages over industrial robotic systems as they are more intuitive to program for non-experts. Intuitive user interfaces are necessary because workers must continually adjust settings and parameters in response to rapidly changing conditions ([Tomori et al., 2024](#)), which is crucial for preventing disruptions and impacts on bricklaying workflows.

[Figure 1](#) presents a visual summary of the key attributes of automated, assistive and collaborative technologies, focusing on their autonomy type, safety design, interactivity and potential for on-site HRC in masonry construction. The table highlights that systems with a higher level of automation require more extensive safety measures to ensure safe interaction with construction workers, which makes them less suited to bricklaying tasks. Cobots such as the MULE and UR16e offer higher safety and task-sharing capabilities, making them more attractive for implementing in on-site HRC workflows in bricklaying.

2.6 Complementary AR enhancements

In recent years, AR interfaces have been increasingly explored as an enhancement to synergise human-machine interactions in HRC workflows ([Chang and Hayes, 2024](#); [Song et al., 2021](#)). Head-mounted AR devices like the HoloLens 2 enhance cobot safety and

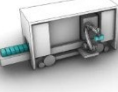
System		Autonomy type	Safety design	Interactivity	Opportunities for on-site HRC construction
Hadrian X		Full automation <i>High payloads & speed</i>	High <i>Isolation zones</i>	Low <i>Remote control</i>	Low <i>-Very large footprint -High cost -Detached housing</i>
Industrial Robot		Full automation <i>High payloads & speed</i>	Extensive <i>Physical barriers</i>	Nil <i>Complex pre-programming</i>	Low <i>-Large footprint -Heavy -High setup & cost</i>
SAM 100		Semi-automated <i>Low payloads High speed</i>	Moderate <i>Isolation zones</i>	Low <i>Material loading</i>	Moderate <i>-High cost -Track mounted -lays bricks in straight runs</i>
MULE		Assistive <i>High payload Moderate speed</i>	Low <i>Mechanical limits</i>	Moderate <i>Lift assist</i>	Moderate <i>-Moderate mobility/footprint -Limited to CMU straight runs</i>
UR-16e		Collaborative <i>Low payload Moderate speed</i>	Low <i>Sensing ISO standards</i>	High <i>Task share</i>	High <i>-Versatile -Small footprint -Highly mobile -Intuitive programming</i>

Figure 1. Comparison and opportunities for on-site HRC in construction

Source: UR16e geometry visualised in Rows 3 and 5 using the Robots plugin for Grasshopper 3D (Solter, 2023). Robotic cell in Row 2 adapted from Sreyas (2025). Figures are created by the Anthony Franze

usability by displaying virtual overlays of a robot's movements. Workers can adjust cobot trajectories to avoid collisions with objects, people and structures (Song *et al.*, 2021).

An on-site study by Mitterberger *et al.* (2020) demonstrated that providing bricklayers with AR interfaces enabled outcomes nearly as precise as those achieved by industrial robots during brick wall assembly. In this research, sensors and scanners accurately registered brick placement within the wall. Meanwhile, bricklayers contributed their expertise and skill to make precise adjustments and manage the application of mortar, ensuring the quality and integrity of the final structure.

In a separate lab-based study by Song and Hahm (2023), bricks were 3D scanned and used to generate point cloud data, which the robot uses to guide pick and place tasks. The researcher manually applies mortar, guided by virtual overlays using AR that facilitate the application process and enable viewing of the robot placement results, making minor manual adjustments to the overall assembly as needed.

AR faces a number of challenges when integrated on-site with cobots, which can lead to bricklayers' resistance to using it (Schein and Rauschnabel, 2023). Key technical issues include ambient light interference, limited field of view, connectivity, latency, holographic drift and the frequent need to scan QR codes to register and track virtual content (Doerner *et al.*, 2022). In addition, bricklayers would require training to safely operate cobots using AR and become familiar with gestural inputs (Ustun *et al.*, 2024)

Practical barriers are equally significant. Unstructured construction environments often lack reliable Wi-Fi connectivity, which impacts real-time responsiveness, as well as adequate

power and charging facilities. Bricklayers frequently handle materials with dirty, wet or abrasive hands, increasing the risk of damage to AR headsets. Extended use of AR headsets can be uncomfortable due to their weight, heat generation and some users’ susceptibility to motion sickness. In addition, others may feel self-conscious about wearing headsets among peers (Ustun *et al.*, 2024). Privacy and surveillance concerns are further amplified by the presence of sensors and cameras capable of tracking biometric data (Schein and Rauschnabel, 2023).

To further understand the potential opportunities, challenges and considerations for the adoption of cobots and AR in the bricklaying workflow of residential housing projects, we aim to understand the lived experiences of bricklayers currently using HRC workflows, along with those considering and exploring cobot adoption.

3. Methods

This article reports on seven semi-structured face-to-face interviews conducted between September and November 2024 with Australian construction company owners, job site forepersons, supervisors, bricklayers and labourers. This research study was approved by Queensland University of Technology’s ethic committee (Approval Number: 8581). All participants provided their informed consent prior to study involvement. The small sample size is indicative of both the limited number of companies in Queensland, Australia that use robots and logistical challenges of participant recruitment, including demanding schedules and frequent site relocations. Nonetheless, the richness of insights gathered and consistency across key findings provide valuable perspectives on the opportunities, challenges and considerations for cobot adoption in bricklaying workflows.

All male participants with bricklaying experience from 7 to 30 years are from four Australian companies, summarised in Table 1. Four participants from one company provided firsthand accounts and unique experiences of using the MULE system on-site for six months. Interviewing both users and non-users of the MULE system for 60 and 90 min allowed us to compare sentiments and discuss considerations for the technology’s future adoption, grounded in experts’ experiences.

Semi-structured interview methods are a cornerstone of qualitative research and one of its most flexible and widely used methods (Bryman, 2012). They are a vital method we use to understand bricklaying experts’ experiences (Tomitsch *et al.*, 2019), and perspectives on using cobots, such as the MULE, their nuanced workflows, along with the challenges, opportunities and considerations for HRC integration in on-site bricklaying workflows. We combined scripted questions to address literature-informed queries and open-ended questions to broaden the discourse and identify new insights.

Table 1. Summary of interview participants, AEC background and job role

Participant ID	Age	Cobot experience	Bricklaying experience (yrs)	Role
1	45	Owner of 3 MULEs	30	Construction manager
2	37	6 months using MULE	25	Supervisor
3	28	6 months using MULE	4	Labourer
4	32	6 months using MULE	8	Bricklayer
5	44	Nil	7	Bricklayer/Labourer
6	30	Nil	11	Job site foreperson
7	48	Nil	25	Bricklaying manager

Source(s): Table by authors

The primary author drafted the semi-structured interview questions, which were then revised with the research team in a workshop and adjusted based on feedback. Given that three participants were not MULE users, we structured questions to accommodate both cohorts. For example, we asked, “Have you used the MULE or similar systems in your bricklaying work?” If they answered affirmatively, we followed up with “How has the MULE system changed your practices and workflows?” and “How do you feel about working alongside a collaborative robot?” “What are some of the main pain points of the system?” and “What are some of the benefits and advantages of using MULE?”

If they answered no, we followed up with: “How do you feel about working alongside a cobot in the future?”; “What challenges do you see with implementing cobots in your workflow?” and “What tasks do you think a cobot could best assist you with?” Several overlapping questions were used for both cohorts, such as “What would a next-generation cobot system need to provide?”, “How do you feel about using AR technology to interact with the cobot?” and “How do you envisage the future of bricklaying?”

3.1 Analysis

This study’s findings are informed by a reflective thematic analysis; a structured method for interpreting, categorising and evaluating qualitative data sets, in this case audio-recorded transcripts (Braun and Clarke, 2021). As described in Figure 2, we distributed interview transcripts among five members of the research team to promote diverse perspectives and reduce bias. Each researcher performed a series of preliminary coding exercises by tabulating portions of the transcripts. Coding is a systematic method for working through a data set at a granular level to identify significant data segments and consider meaningful

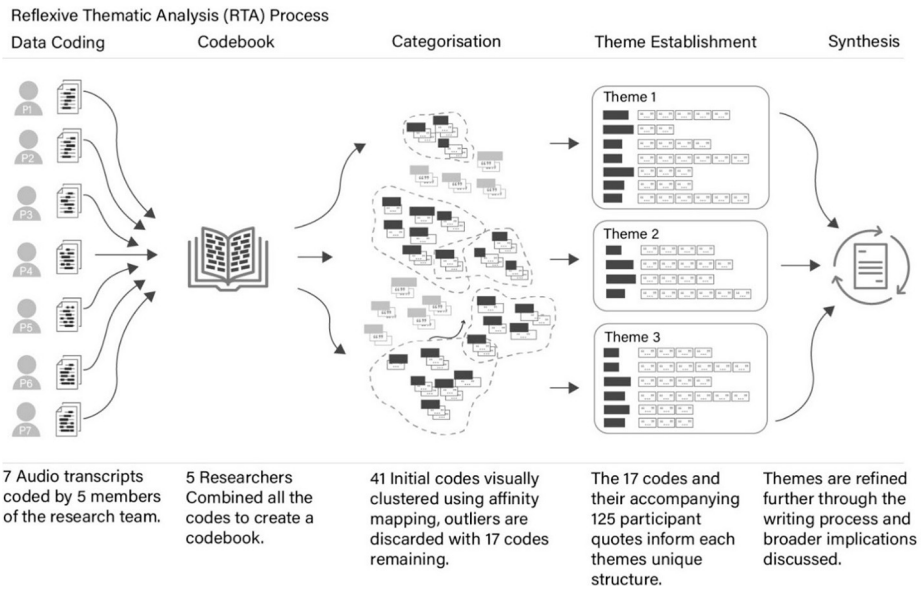


Figure 2. RTA process

Source: Anthony Franze’ own work (2025)

descriptions for further analysis. Once initial codes were defined, the team shared codes and established a codebook as a common framework for internal consistency.

The codebook clarified the analysis parameters and aligned the team's understanding of the data set. Codes were then visually recreated in web-based software, Miro, using digital sticky notes arranged with their corresponding data segments to inform an online visual affinity map. Visually clustering the codes allowed the team to identify relationships and patterns across the data set—several refinement phases culminated in the development of three themes outlined in the results section. In the results section, we outline specific quotes from participants that illustrate a particular theme, referring to participants' quotes as (P...) and italicising them.

4. Results

Exploring the experiences and perceptions of Australian bricklaying professionals with cobots provides valuable insights into their potential integration within the construction sector. This section presents three key themes identified through the RTA process:

- (1) Theme 1 establishes MULE's productivity and workforce outcomes.
- (2) Theme 2 examines the contemporary on-site operational and logistical challenges of MULE deployment.
- (3) Theme 3 addresses the key considerations for successful on-site cobot deployment.

These findings are further synthesised and critically discussed in the subsequent discussion section, where the broader considerations for cobot deployment in the construction industry are outlined and aligned to [Davis's \(1989\) Technology Acceptance Model \(TAM\)](#).

4.1 Theme 1: Enhancing bricklayer productivity, longevity and diversity through collaborative robotics

According to users, MULE is not typically used for residential brickwork. Instead, bricklayers use the device to build commercial and infrastructure projects. Optimal efficiency gains are realised when constructing 20 metre high mechanically stabilised earth (MSE) retaining walls or long stretches of inter-tenancy walls. For projects that use CMU blockwork, workers' productivity is enhanced because the MULE provides an assistive lift, allowing workers to pick up blocks directly from pallets. Otherwise, 27-kilo-weighted double-length CMU blocks would require two people to lift. When asked why MULE is not used for brickwork, P4 stated this was a current limitation of the MULE system, "If it's a block wall for houses, we do that, but we don't do the bricks on the outside [...] a lot of residential houses have curved walls" (P4).

P1, a MULE owner with 30 years of experience in bricklaying and construction management, emphasised the importance of collaborative robotic systems for the future of bricklaying. P1 viewed cobots as essential for sustaining productivity and addressing the demanding nature of masonry work, illustrated in Plate 5a and 5b (to be presented shortly in the Theme 3 section). The process of a bricklayer applying mortar and placing bricks involves continual bending and stretching, as well as the need to navigate string lines, wall corners and ground obstacles, all of which contribute to the physical strain and complexity of the task.

In P1's perspective, the goal of robot integration is not to replace human workers, but to support them, stating, "You don't want something that's going to take the job away" (P1). By introducing the MULE, P1 increased workforce productivity, simplified workflows and eased workers' physical strain. Interestingly, experienced employees who were thought most suitable for the device were not the ones who adapted best: "I got all the older guys within the

company inducted and trained to use them, thinking they would be best suited. And that was completely the opposite” (P1).

Adopting robotics enabled P1 to establish a point of differentiation within the construction sector, promoting the company as an innovator, bridging the sector’s workforce diversity challenges by hiring the company’s first female bricklayer. P3, a labourer with 4 years of experience, added that because MULE eliminates heavy lifting, experienced workers could remain in the profession longer, stating, “someone in their 80 s could probably use it and not struggle” (P4). Beyond the immediate business benefits, P1 is adamant that devices like MULE are pivotal to the viability of the entire profession, and if robot adoption rates do not increase, “then the future of masonry is not a pretty one” (P1). Going into detail that “not many of the younger generation coming through are interested in the job” (P1), and fearing the bricklaying craft will be lost to the prefabrication of walls in warehouses.

All bricklayers shared a strong sense of pride in their unique craft and tangible outcomes of their work. However, there are stark differences in their perspectives regarding the effects of robotics on job security. Non-MULE users expressed greater adverse sentiments about future employment prospects compared to MULE users. P6, a site supervisor with 11 years of bricklaying experience, believed robots would inevitably impact bricklayers’ livelihoods and alter work roles, particularly the task of laying bricks. P6 further explained how the role of labourers would be at risk, “if it’s for the labouring aspect, if it comes in and does that, what are they going to do?” (P6).

P2, a MULE user with 25 years of bricklaying experience, welcomed its use but was wary of accidentally damaging the machine during daily activities. They perceived the device as highly complex, expensive and beyond their capability to repair, if they damaged it. P5 argued that new approaches are needed, “bricklaying has been done the same way since the pyramids” with the same tools “shovels, wheelbarrows, trowel and flat pointers” (P5). Having used MULE for six months, P3 did not see the machine as being a complete match for human workers on the job site and were adamant that they did “not see this job as going away to robots” (P3).

Labour unions play a significant role in the Australian construction industry, making their acceptance of new technology paramount to successful integration. According to P1, union representatives are likely to view the MULE system favourably, as “the union is about the worker, then they should not have an issue with this” (P1), highlighting the alignment between the MULE’s assistive and collaborative function and union priorities.

From a financial perspective, P1 outlined the potential return on investment associated with deploying the MULE system. If the device is used on-site as consistently as employees, costs could be recouped in just over a year. MULEs offer operational advantages such as the capability to work continuous 24-hour shifts, eliminating concerns around attendance and work cover claims. P1 further noted savings could be achieved in “payroll tax, superannuation, insurances, and they turn up [...] and give the same performance every day” (P1).

4.2 Theme 2: On-site operational and logistical challenges of MULE deployment

MULE assists bricklaying teams with block work, but P1 only uses it across 30% of their current work sites. The underuse is because the MULE system requires sites that can accommodate heavy and large trucks to transport and manoeuvre the device around the site. P3 elaborated that constraints include “access, egress, having space to move things, height, power”; however, “where the jobs, right [...] It’s perfect” (P3). According to P1, once MULE is set up, moving it is quick, simple and only requires a pallet jack. P2 finds moving the MULE system around can prove challenging due to its top-heavy nature and recommends the incorporation of an off-road wheel, so “you could drive it [...] like the electric scissor” (P2).

The MULE system is moved more frequently on Australian sites because of its design to span six metres to accommodate American control joints. In contrast, Australian joints are spaced at 8-metre intervals. In addition, there are further challenges in moving the system around the site, which requires space for the transportation device, as P3 explained you “have to make sure it has room to move without getting blocked in” (P3). For P2, it is important to be able to re-position and set up the MULE as quickly as possible due to the time constraints bricklayers face given the sequencing and prioritisation of other trades on work sites, “you see that [the site priority] is not ours it’s “hurry up and get out the way because the form workers are coming through” (P2).

MULE operators have also encountered limitations when using it at height on scaffolding to complete higher wall sections. Consequently, the system is currently not fully used, with bricklayers still tending to higher wall sections, as illustrated in [Plate 3](#).

According to P1, positioning and setting up the MULE on a concrete slab “can be done in 10–15 min” (P1), but to lift it onto a scaffold requires a crane or forklift, and above six metres, anchoring is required. Moreover, given site scheduling constraints, organising the crane requires swift coordination; otherwise, there is a risk of the device not being used. P1 explained that there are also usability challenges to overcome when using a MULE on a scaffold. “We struggled a bit with the responsiveness. It didn’t really suit us, so we don’t do any scaffolding work with them anymore” (P1). Although MULE can confidently reach over two metres, the awkwardness of moving CMUs suspended from a long cord means this feature is underutilised. This limitation, combined with the use of larger custom CMU blocks, can introduce unforeseen safety risks, as noted by P3, who witnessed “the bricklayers laying a double block, by hand” (P3).

4.3 Theme 3: Exploring key considerations for efficient on-site cobot deployment

We asked all seven participants what a next generation cobotic solution would require in laying bricks more efficiently. We inquired because although the MULE system is highly



Plate 3. Challenges setting up the MULE on unstructured sites mean bricklayers still manually lay CMUs at height without its assistance

Source: Armstrong Bricklaying. Used with permission

beneficial for blockwork, it is not particularly suited to the construction of the intricate brick walls seen in smaller residential properties. As P1 confirmed, “[MULE] does not make sense for brickwork as they cannot compare with the speed of bricklayers” (P1). Despite this viewpoint, P1 showed interest in exploring the integration of smaller compact cobots to assist bricklayers on residential sites.

To gain further insights into the key considerations for a next-generation HRC workflow, we inquired about its overall form and features, as well as the specific tasks where it would be most beneficial. P1 outlined that the device would need to be as compact as possible and self-levelling. P2 agreed that a device would need to be more “streamlined” and “on tracks or something that you can remotely control to move it” (P2). Both P5 and P6 agreed that access is limited for moving equipment around, past and through obstacles, as can be seen in [Plate 4a](#) and [Plate 4b](#). We observed space limitations first-hand on-site with P6 and P7 at a new housing development in Brisbane, Queensland. P7 pointed out how systems like Hadrian X would be hindered by the lack of access, as well as the fact that numerous construction teams work simultaneously in a dense area.

Currently, there is a challenge in providing sufficient on-site power to construction crews for their existing machinery and additional devices, such as MULE. P1 has found a workaround to this issue by developing and upgrading the MULE’s battery system, which is enclosed in a waterproof compartment and provides seven hours of operation time over four days. P3 explained how “they [MULE] need a clean power channel, nothing else can be



(a)



(b)

Plate 4. Site photographs from a new housing development in Brisbane, Queensland. (a) Limited access pathways between structures. (b) Equipment manoeuvring challenges due to spatial constraints and site congestion (2025). Images used with permission in accordance with ethics approval (Approval Number: 8581)

Source: Authors’ own work

plugged into it [...] the generator on the mule itself is a great idea because then it has its own power” (P3).

Both P6 and P7 are non-cobot users. They felt a cobot did not appear suited to “laying the bricks” (P6) as illustrated in [Plate 5b](#). P7 felt a cobot would be most helpful for “mixing mortar and pushing wheelbarrows, transporting the mud to where we need it” (P7). According to both P6 and P7, they lose significant time preparing and applying mortar ([Plate 5a](#)), which they, along with other participants in this study, refer to as “mud” (P6) (P7). P6 also inquired whether a cobot could replace wheelbarrows and if it “could spread mud between each brick” (P6), as this is a highly demanding task.

Beyond mortar application and material transport, participants identified several further tasks for a cobot. For example, replacing hazardous manual water saw brick cutting operations. In residential builds, a portion of bricks is pre-cut to ensure that each row of bricks is seamlessly and aesthetically integrated around openings and finished correctly at the lintels. Obtaining the measurements for each cut is tedious. Cuts can vary from 145 mm to 220 mm, and a worker needs to obtain all measurements and provide them to the brick saw operator, which can take three to four hours per house. P5 agreed that replacing the task of brick cutting could alleviate potential hazards “if I thought about any point where I found the work site dangerous, that’s the one. That’s the saw” (P5).

P5 suggested cobots could have an integrated computer vision (CV) system that monitors the thermal properties of bricks and mortar as workers are continuously monitoring the state of mortar joints curing process and, “if it’s too wet, you get a big shine on the Joiner [...] if



Plate 5. Site photographs showing manual bricklaying tasks. (a) A bricklayer bends down to apply mortar (“mud”) evenly across the brick face. (b) Brick placement in a constrained area requires stretching and navigation around corners, string lines and structural features (2025). Images used with permission in accordance with ethics approval (Approval Number: 8581)

Source: Authors’ own work

it's been drying too long, it's difficult to finish. It crumbles" (P5). P5 also asked whether CV could provide quality control assistance, as there are colour variations between brick pallets, and it's the labourers' role to evaluate and disperse bricks to ensure the façade has an aesthetically cohesive colour appearance. P5 also discussed the incorporation of AR to provide labourers and bricklayers with visual information about the job site. For example, to prevent errors, check datums and view walls before construction, and determine the number of half bricks to initiate the brick cutting process earlier.

Whilst size and access are the core concerns amongst bricklayers for integrating a cobot on site, P5 raised valid concerns on "the sequence of construction, sometimes brickies are on-site, sometimes there are four trades on-site at a time" (P5). P5 further elaborated that there would need to be a way to interact with cobots seamlessly and in a similar manner to existing co-workers; therefore, the "logical step would be to use humanoid robots to take over the arduous tasks" (P5).

5. Discussion

The study examines Australian bricklaying professionals' perceptions of MULE, cobots and AR, highlighting key considerations for the integration of HRC in residential construction. Given the variability of tasks and site complexity, participants underscore the importance of collaborative strategies. A human-centred approach is required, as a predominant focus on automation has previously impeded the integration of industrial robots (Reinhardt *et al.*, 2020). This section interprets the findings through the frameworks of technology acceptance and HRC, focusing on the considerations for system design, adoption and future research directions.

5.1 User acceptance and technology adoption

In developing a human-centred approach to cobot adoption in bricklaying, it is important to examine and understand how workers and teams accept and integrate new technologies on construction sites. The technology acceptance model proposed by Davis (1989) provides a foundational framework for understanding user adoption tailored to digital technology and is comprised of three core constructs. Perceived usefulness (PU), perceived ease of use (PEOU) and subjective norm (SN). PU refers to the extent to which users believe that using technology will enhance their job performance. PEOU reflects the degree to which users believe technology is easy to learn and operate. SN relates to the social pressure of using new technology in the workplace (Nnaji *et al.*, 2023).

In response to our research question "What are the opportunities, challenges and considerations for collaborative robots and augmented reality adoption in the bricklaying workflow of masonry construction?" we used the TAM construct to identify the perceived challenges of adopting cobots to masonry construction.

5.1.1 Perceived usefulness (PU). MULE operators demonstrated a notably higher PU regarding cobot integration compared to non-users. Insights from P1 and P3 emphasised how collaborative systems like MULE can play a pivotal role in sustaining the bricklaying profession. They further explained how it reduced physical strain, meaning that experienced workers could remain active in the trade for longer. MULE operators P1 and P2 agree that the industry needs to embrace new tools, such as cobots, to remain competitive, as surmised by P1, "if this type of technology is not adopted, then the future of masonry is not a pretty one" (P1). These sentiments are vital to consider given the construction sector's historically poor productivity, workforce shortages and failure to meet residential housing targets (Master Builders Australia, 2024; Regona *et al.*, 2022).

Non-users and older MULE operators exhibited open scepticism and lower PUs. Such as MULE user P3, believing that bricklaying is too nuanced and fast-paced for robots and does “not see this job [...] going away to robots” (P3). Mature workers also indicated a greater reluctance to alter their established practices. Non-users, like P6, held concerns about working alongside cobots and regarding job security by saying, “It’s a bit scary actually to think about it, that’s the way that everything may be turning, but if it is going to be laying bricks, then what am I going to do?” (P6).

5.1.2 Perceived ease of use (PEOU). Although having positive sentiments about MULE, P3 also expressed concerns about the complexity of the device, which indicates a lower PEOU. Usability challenges at height due to inadequate responsiveness during the manoeuvring of larger CMU blocks highlight the need for cobots to be intuitive to use on-site with high responsiveness. Solutions require working closely with bricklayers to consider ergonomic factors across a range of bricklaying activities.

Several factors contributed to MULE’s low 30% utilisation. Similar to Hadrian X, deploying the MULE to the site requires ample ingress and egress for large machinery, such as trucks and cranes, to position the system in the correct location (Ambrosino *et al.*, 2023). The size and high centre of gravity of the MULE system make it challenging for bricklayers to relocate it and transport it quickly around the site. This challenge is compounded by the need to respond to Australian control joint spacing and re-levelling on uneven terrain. Having the ability to set up a cobot device quickly is important, as long delays can interfere with site scheduling requirements.

5.1.3 Subjective norm (SN). P1 felt that the MULE positively contributed to their company’s perception as an innovator within the profession, which made it attractive to the next generation of tradespeople. P1’s sentiments are important, given the construction sector’s high exit rate, combined with a dwindling interest among prospective apprentices (Master Builders Australia, 2024). Cobot adoption, along with devices such as MULE, appears to be influenced by societal expectations, for example, improving a company’s reputation and aligning with evolving workforce values. P1’s experiences highlight the potential for cobots to make the profession of bricklaying more inclusive for underrepresented groups.

By facilitating less demanding and more productive workflows, the MULE helped P1 broaden their workforce diversity, enabling the recruitment of workers, including female bricklayers. Using more female workers aligns with industry endeavours such as the “Aussie Female Brickies” initiative by Brick and Block Australia, a not-for-profit, social enterprise that aims to improve employment opportunities for young Australians (Brick and Block Careers, 2024).

However, among non-users, more resigned opinions towards cobots were observed, as fears were expressed regarding the impacts of cobots on roles such as labouring and bricklaying. Moreover, non-users’ cautious framing of potential cobot tasks, often limited to auxiliary roles, may reflect an underlying limited understanding of cobot capabilities and the use case for their adoption. For future research, subjective norms need to be considered, as they can not only facilitate but also hinder cobot adoption. In summary, future research should consider the positive and negative perspectives of bricklayers outlined in Table 2, based on Davis’ TAM constructs, to increase HRC technology adoption.

The next section outlines the key considerations and opportunities for adopting cobots in bricklaying workflows, based on bricklayer insights. We identify and explain potential HRC bricklaying tasks for further research to enhance bricklaying construction to be more productive, safe and engaging.

Table 2. Summary of bricklayers' perspectives on cobot adoption aligned with TAM constructs

TAM construct	Positive perspectives	Negative perspective
Perceived usefulness (PU)	MULE users (P1, P2, P3) found the device beneficial for reducing physical strain, extending career longevity, and maintaining competitiveness	Non-users and older MULE users expressed scepticism, viewing bricklaying as too nuanced and fast-paced for robotic systems
Perceived EASE of use (PEOU)	MULE users acknowledged challenges related to size, weight, and manoeuvrability but maintained overall positive sentiments	Some MULE users feared accidental damage and found the device complex, indicating lower ease of use
Subjective norm (SN)	Users felt that MULE enhanced the company's reputation and helped attract a diverse and younger workforce	Limited understanding of cobot capabilities, the business, and use case for their organisation. Fear of job displacement is high in non-users

Source(s): Table by authors

5.2 Considerations for HRC in bricklaying processes

[Figure 3](#) synthesises study findings visually, outlining our key considerations and benefits for HRC in bricklaying processes. These inform potential bricklaying activities for using HRC to enhance productivity, efficiency and safety relative to the unique context needs of bricklaying professionals.

Rethinking existing workflows: Participants raised important questions regarding whether a cobot could lay bricks as quickly as a human worker. While cobot speed remains a challenge, there may be worthwhile productivity gains, given increases in precision, reduced ergonomic concerns and the potential for constructing sophisticated wall designs. Cobot integration raises the possibility of reducing worker fatigue, injury and more sustainable workflows.

Augmenting human skills: Cobots are valued for their precision, safety and endurance capabilities ([Loy et al., 2024](#)). Dialogue with both user groups confirmed that an HRC workflow is necessary because humans are better equipped to address contextual site challenges related to unstructured environments, varied workflow sequences, tolerances and material differences ([Jahn, 2022](#)).

Interactivity and control: Cobots must support intuitive interaction. Teaching-by-demonstration capabilities allow workers to guide cobots through intricate tasks, fostering trust and adaptability. This interactive control is especially valuable in workflows that require frequent adjustments.

Ease of use and setup: Cobots should be easy to set up, move and deploy in close spaces. MULE workers identified priorities including quick deployment, high manoeuvrability, battery operation, self-levelling and compliance with local regulations and codes for efficient use on site.

Scale and spatial efficiency: A modular and compact cobot design is critical for residential bricklaying sites, where space is often limited. A smaller footprint improves manoeuvrability and reduces interference with other workers and trades, enhancing overall site efficiency.

Innovation in Industry: Given industry volatility, it is crucial to address the potential impact of robot integration on workers, labour unions and peak bodies to communicate that cobot integration is to support, not replace, existing roles and aims to extend the viability of the bricklaying profession.

Considerations for HRC in Masonry Processes	Opportunities for Masonry Processes
Rethinking Existing Workflows	-Reduced worker fatigue and injury -Improved worker quality of life -Enhanced productivity
Augmenting Human Skills	-Higher precision and repeatability -Workers concentrate on craft aspects and resolving site challenges
Interactivity & Control	-Intuitive interactions -Teach by demonstration -Virtual/remote operation for builds
Ease of Use & Setup	-High maneuverability -Self-powered -Self-leveling -Easier to anchor at heights
Scale & Spatial Efficiency	-A compact footprint allows for use on more sites -Less encroachment in the workspace
Innovation in Industry	-Gender diversity -Longevity of bricklaying craft -Complex brick wall designs
Complementary Technologies	Augmented Reality -Reduced worker ambiguity -Enhanced robot interactions Computer Vision -Improved quality assurance -Enhanced aesthetics
Robot Form	Robot-arm -Lower cost/mount on mobile platforms Humanoid -Enhanced dexterity, site navigation Quadrupedal -Enhanced load carrying, site navigation
Affordability & Accessibility	-Accessible to smaller companies -Improved industry adoption

Potential HRC Masonry Tasks

- transporting,
- cutting, and
- preparing mortar and bricks,
- spreading mortar on bricks,
- providing them to the bricklayer,
- placing bricks,
- assisting with quality assurance tasks.

Figure 3. Synthesis of study findings informing potential HRC bricklaying tasks
Source: Anthony Franze own work (2025)

Complementary technologies: Participants identified several promising applications for AR and CV. AR can reduce task ambiguity, improve communication and enhance cobot interaction by overlaying virtual guidance in real-time. CV systems were proposed to assist with quality control, such as monitoring mortar curing and ensuring consistent brick aesthetics.

Robot Form: P5 suggested that humanoid robots may offer advantages due to their ability to navigate complex, cluttered environments and perform dextrous tasks. Whether bipedal, quadrupedal, or robotic-arm-based, cobots must be designed for seamless interaction with workers to maintain safety and support collaborative workflows. Similar to the various tools

used in construction, different types and forms of robots may work together with people or across different parts of a construction site, depending on the task requirement. One size does not fit all.

Affordability and accessibility: Given that many bricklaying businesses are small or subcontracted, cobot systems must remain cost-effective and appropriately scaled. Lean, modular designs can help ensure accessibility and encourage broader adoption across the sector.

Potential HRC masonry tasks to be explored: These activities include transporting, cutting and preparing mortar and bricks, spreading mortar on bricks, providing mortar to the bricklayer, laying bricks and assisting with quality assurance tasks. These activities can be explored in future studies involving cobotics and AR utilisation in residential masonry construction for bricklaying.

5.3 Limitations

Before we outline our future research directions, we need to acknowledge the limitations of this study. First, the relatively small sample size may limit the generalisability of findings and may not be representative of all bricklayers' views across Australia. Similarly, technology exposure was limited to the MULE device and may not account for other systems currently in use or under development. Third, non-MULE users' prior knowledge of cobot and AR technology was limited, which reduced the depth of discussion into specific interaction capabilities explored in their workflows. This limitation also reflects a trend for smaller bricklaying companies, who often lack the access, research and development resources to explore emergent technology adoption. Similarly, discussions about AR technology with all participants were of a higher level, rather than in-depth, which limited exploration into specific HRC interactions. Finally, while TAM provides a useful framework for this study, alternative models such as the unified theory of acceptance and use of technology (UTAUT) by Venkatesh *et al.* (2003) may afford additional insights and be considered in future research.

5.4 Future research directions

In future research, we will develop HRC systems tailored to the specific workflows of bricklayers. These design-to-construction processes will take a human-centred approach and be co-developed with practitioners to reflect on-site practices (Benyon, 2019). As outlined in Figure 4, building on this study's findings (Phase 1), the subsequent phases will focus on optimising brick stacking to improve efficiency and reduce waste. AR will support communication and safety by helping bricklayers interpret cobot movements. We will also explore alternative binders to enhance structural performance and speed. Prototypes, including cobots and potentially humanoid robots, will be tested under realistic conditions and refined in collaboration with bricklaying professionals.

6. Conclusion

This study investigated bricklayers' perspectives on cobots and AR in residential brick dwelling construction. Through interviews with cobot users and non-users, we identified key opportunities, challenges and considerations for effective HRC workflows. Findings revealed that cobot systems, such as MULE, reduce physical strain and effort, foster new, efficient practices and increase workforce diversity. However, cobot adoption remains limited, especially in residential bricklaying, due to on-site logistics and usability issues. In addition, senior MULE users and non-cobot users expressed concerns about the complexity of cobots and potential job displacement.

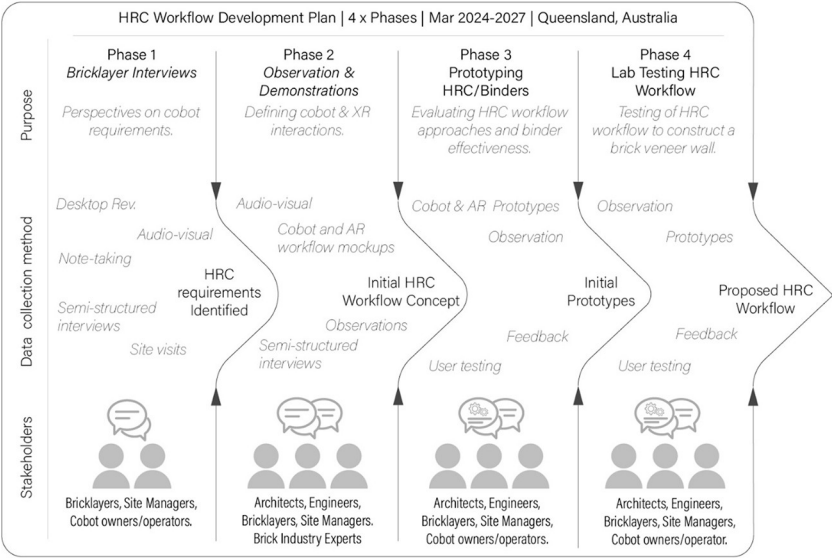


Figure 4. An overview of this study’s role in our future research
Source: Authors’ own work (2025)

This study identified several considerations for HRC in bricklaying processes. The big picture impact of these technologies in the bricklaying sector is the first consideration if we want to create change. Secondly, we need to rethink existing workflows and create new ones with additional enabling technologies, augmenting human skills to provide interactivity and control. Thirdly, we need to consider the robot form, type, affordability, scale and spatial efficiency for ease of use and set-up. And finally, many bricklaying tasks can be enhanced through HRC.

Our research underscores the importance of HRC workflows specifically designed to accommodate the nuanced and dynamic nature of residential bricklaying. Bricklayers emphasised the need for cobots to be compact, intuitive and adaptable to unstructured site conditions. Complimentary AR technology was also seen as a promising tool to extend cobot interaction, task precision and safety, though its application in bricklaying remains underexplored.

In alignment with user adoption principles outlined by TAM, we highlighted how perceived usefulness, ease of use and subjective norms need to be considered as influencing factors in adoption. These factors, along with bricklayers’ recommendations, inform future design considerations, underscoring the need for human-centred solutions co-developed with bricklayers to align with their workflows and values.

Future work will develop cobot systems specifically configured to support the nuanced workflows of bricklayers. These design-to-construction workflows will be co-developed with bricklayers to ensure alignment with on-site practices. Further, by tailoring cobot technologies to the contextual and task-specific considerations of bricklaying, we aim to facilitate meaningful integration into construction practice, enhanced productivity, safety, efficiency and promote broader industry adoption.

Ultimately, this research contributes to bridging the gap between traditional on-site construction practices and emerging technological innovation. By addressing critical workforce shortages and supporting the long-term sustainability of the profession, this research also aims to make a meaningful contribution to alleviating the housing crisis in Australia.

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