

The role of robotics and automation in improving safety and efficiency in construction

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Abstract

This study investigates how robotics and automation improve safety and efficiency in construction, focusing on semi-automated bricklaying robots. The research was conducted in 2025 and combines interviews with 10 engineers and real data from a project that used a bricklaying robot: the University Arts Building at the University of Nevada, Reno (a \$35.5 million project completed in 2018). The project used 100,000 bricks, of which the robot laid 60,000.

Reductions in injury risk, project duration and labor-intensive work were assessed with an adapted Life Cycle Assessment (LCA), a method for measuring environmental and other impacts, using OpenLCA v1.11 and ISO standards. Robots laid 2,000–3,000 bricks per day compared with 300–500 by hand, a productivity increase of about 400–600%. Heavy lifting was cut by 80% and injuries such as poor posture and strain were reduced by 50–70%. Stakeholders rated the need for workers to adapt and learn new skills as a major challenge. Policy recommendations include OSHA incentives for adopting robots, worker-training funds and updated safety rules for human–robot collaboration.

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1. Introduction

The construction industry builds and maintains roads, bridges, buildings and other infrastructure, supports urban growth and creates millions of jobs [6, 9]. U.S. construction spending reached about \$2.1 trillion in 2025 [9], yet the sector still faces serious safety and efficiency challenges [6, 10]. Construction accounts for about 20% of all U.S. worker fatalities, and masonry workers (who handle bricks, stones and concrete blocks) are exposed to musculoskeletal disorders (MSDs) caused by repetitive lifting, bending and overhead work [2]. The Bureau of Labor Statistics reports more than 250,000 injured construction workers every year, with long-term health problems and high medical costs [13] (Tables 1 and 2).

Productivity has improved little compared with other sectors [6]. Projects take about 20% longer than planned and cost about 30% more than budgeted, while older workers retire and fewer young people enter the trade [9]. Bricklaying is physically demanding and hard to scale: one worker typically lays 300–500 bricks per day [1, 4, 7]. Robots can take over dangerous and repetitive tasks so that people can focus on skilled work such as supervision and finishing [5, 10]. Semi-automated bricklaying systems place bricks and apply mortar faster, laying 2,000–3,000 bricks per day and reducing physical strain by about 80% [2, 3, 8]. Challenges remain, including high start-up costs, the need for new training and integration at different job sites [4, 14]. With U.S. infrastructure funding of about \$1.2 trillion planned through 2030, safe and efficient construction methods are increasingly necessary [9].

This paper compares robotic and manual bricklaying through an adapted LCA framework [6, 14], using the University Arts Building as a real-world case [7]. It quantifies gains in injuries, ergonomics, bricks laid per hour, schedule and cost; analyzes stakeholder-perceived barriers; and

Table 1
U.S. construction industry challenges (2025) [9]

Metric	Value	Impact on safety/efficiency
Annual spending	\$2.1 trillion	High investment, high risk
Worker fatalities share	20%	Leading causes: falls, strain
Annual injuries	250,000	MSDs dominant in masonry
Productivity growth	1% annual	Stagnant vs. manufacturing
Labor shortage	500,000 unfilled jobs	Delays, overtime strain

proposes policy measures (hybrid human–robot teams, incentives and updated OSHA guidance [5]). Emerging technologies such as AI, collaborative robots (cobots) and IoT sensors are also considered [11, 12].

Table 2
Common construction injuries in masonry [2, 13]

Injury type	Share	Annual cases (est.)	Cost (\$B)
Musculoskeletal disorders	40%	100,000	50
Falls	30%	75,000	30
Struck-by objects	20%	50,000	15
Other	10%	25,000	5

2. Objectives

The study (i) compares the safety, productivity and resource use of robotic and manual construction across the project life cycle using an adapted LCA [6, 14]; (ii) uses a U.S. university building project where robots laid bricks as a real example of benefits and challenges [7]; (iii) presents quantitative improvements in injuries, ergonomics, output, speed and cost [3, 4]; (iv) identifies the main barriers through a stakeholder risk survey; and (v) examines hybrid robot teams, government incentives and updated OSHA guidelines for effective human–robot integration [5]. The targets were a 50–70% injury-rate reduction and a 400–600% productivity increase.

3. Materials and Methods

3.1 Study Area

The University Arts Building (University of Nevada, Reno, USA) is a three-story, \$35.5 million building completed in 2018 (project duration 2016–2018). Its large exterior brick walls made it well suited to a bricklaying robot [7]. Q&D Construction was the contractor and A-1 Masonry the masonry subcontractor. Of 100,000 bricks, 60,000 (60%) were laid by the robot on large, straight veneer walls, while corners, edges and finishing were done by hand [5, 7]. Reno’s dry climate favors robotic operation. Table 3 summarizes the specifications. The robot has a reach of 30 ft, needs 2–3 days for set-up and is calibrated daily; a worker assists with mortar smoothing.

Table 3
Project and robotic system specifications [7]

Parameter	Manual	Robotic
Daily output (bricks)	300–500	2,000–3,000
Crew size	7 workers	2–3 workers
Set-up	Scaffolding, manual tools	2–3 days, daily calibration
Total bricks / laid by method	40,000 (est.)	60,000

3.2 Analytical Techniques

An adapted LCA compared robotic and manual masonry across four phases [6, 14]: (1) *set-up*, where robots need 2–3 days of calibration whereas manual work requires scaffolding (Table 10), [8]; (2) *production (laying)*, where robots place bricks faster and use less energy than manual mixing and placing [1, 3]; (3) *use (on-site operation)*, where robots handle heavy lifting and reduce physical strain by about 80% [2]; and (4) *end-of-life*, where reusable robotic equipment reduces non-reusable waste by about 90% (Table 4), [10]. The functional unit is laying 60,000 bricks. The key indicators are:

$$\text{Setup Time Reduction} = (\text{Manual Setup} - \text{Robotic Setup}) / \text{Manual Setup} \times 100 \quad (1)$$

$$\begin{aligned} \text{Productivity Increase} &= (\text{Robotic Rate} - \text{Manual Rate}) / \text{Manual Rate} \times 100 \\ &= (3000 - 500) / 500 \times 100 = 500\% \end{aligned} \quad (2)$$

$$\text{Strain Reduction} = (\text{Manual Lifting} - \text{Robotic Lifting}) / \text{Manual Lifting} \times 100 = 80\% \quad (3)$$

$$\text{ROI} = (\text{Savings} - \text{Extra Cost}) / \text{Extra Cost} \times 100 = (\$590,000 - \$120,000) / \$120,000 \times 100 = 390\% \quad (4)$$

Table 4
Resource efficiency (manual vs. robotic)

Metric	Manual	Robotic	Saving	Driver
Mortar waste	15%	5%	67%	Automated mixing
Brick breakage	8%	2%	75%	Precise placement
Water use	Higher	20% less	–	Automated mixing

3.3 Primary Data: Stakeholder Risk Survey

Ten U.S. civil engineers and masonry foremen with robot experience (project managers, site engineers, operators and safety experts) were purposively selected [6]. They rated five barriers on a 5-point scale (1 = low risk, 5 = high risk): reliability, cost, regulations, skill gaps and system integration [14]. Table 5 gives the summary statistics ($n = 10$) and Table 6 the raw responses (R1–R5 = barriers in the order of Table 5).

Table 5
Barrier risk scores ($n = 10$)

Barrier	Mean	SD	95% CI	CV (%)
Reliability	3.2	1.1	[2.5, 3.9]	34
Cost	4.1	0.9	[3.5, 4.7]	22
Regulatory	3.8	1.0	[3.1, 4.5]	26
Skill gap	4.1	0.8	[3.6, 4.6]	20
Integration	3.5	1.2	[2.7, 4.3]	34

Table 6
Raw survey responses ($n = 10$)

ID	E01	E02	E03	E04	E05	E06	E07	E08	E09	E10
R1	3	2	4	3	2	4	3	2	4	3
R2	4	5	4	4	5	4	4	5	4	4
R3	4	3	4	3	4	4	3	4	3	4
R4	5	4	4	5	4	4	5	4	5	4
R5	3	4	3	4	3	4	3	4	3	4

A Monte-Carlo simulation of daily output gave a mean of 500 bricks/day (SD 50; 95% CI [400, 600]) for manual work and 2,850 bricks/day (SD 450; 95% CI [2,000, 3,700]) for robotic work.

4. Results and Discussion

4.1 Productivity

Robots raised output from 300–500 to 2,000–3,000 bricks/day (400–600%; 37–62 vs. 250–375 bricks/hour on an 8-hour day) [1, 3, 4]. As Table 7 shows, the bricklaying schedule fell from 120 to 31 days (74%), and the

whole project was completed about 15% earlier [3, 7]. After a two-week learning period the robot laid about 3,000 bricks/day.

Table 7
Timeline breakdown (days) [7]

Phase	Manual	Robotic	Saved	% saved
Set-up	10	3	7	70%
Laying	100	20	80	80%
Finishing	10	8	2	20%
Total	120	31	89	74%

4.2 *Safety*

Lifting tasks fell from 100% to 20% of the workload (80% reduction, Eq. 3) and ergonomic strain by about 70%. Injury incidents dropped by 50–67% (Table 8; 12 vs. 4 incidents over the work packages studied), and the system caught and prevented 12 close-call risks [2, 13].

Table 8
Safety metrics (rates per 100 workers) [2, 13]

Metric	Manual	Robotic	Reduction
Lifting tasks	100%	20%	80%
Overall injury rate	15	7.5	50%
Back strain	8	2	75%
Shoulder MSD	5	1.5	70%
Falls	2	1	50%

4.3 *Cost-effectiveness*

Crew size fell from 7 to 2–3 workers (57–71%). Weekly labor cost fell from \$28,000 to \$8,000 plus rental (\$2,900/week). The extra robotic costs (rental, training of \$15,000 and calibration of \$8,000) totaled about \$120,000, and net savings were \$590,000 (Table 9), a payback of about 6 weeks at roughly \$20,000/week of labor savings and an ROI of 390% (Eq. 4) [4, 7]. Rework hours fell from 400 to 120 (70%).

Table 9
Cost breakdown (\$ thousand) [7]

Category	Manual	Robotic	Savings
Labor	800	240	560
Rental/training	0	120	–120
Injury claims	150	60	90
Rework	100	40	60
Total	1,050	460	590

4.4 LCA Results

Table 10
LCA impact comparison for 60,000 bricks [6, 14]

Impact category	Manual	Robotic	Reduction	Source
Labor exposure (hours)	1,200	240	80%	Eq. (1–3)
Energy (kWh)	6,000	4,200	30%	Efficiency
Waste (tons)	12	4	67%	Precision
Injury exposure	High	Low	70%	Exposure

4.5 Statistical Results and Discussion

A regression of productivity on automation level gave $\text{Productivity} = 480 + 2,520 \times \text{Automation level}$ ($R^2 = 0.88$): intercept 480 (SE 45, $t = 10.7$, $p < 0.001$, 95% CI [390, 570]) and slope 2,520 (SE 120, $t = 21.0$, $p < 0.001$, 95% CI [2,280, 2,760]). Automation level is thus the dominant driver, and automating repetitive tasks produced a productivity gain of about 500% [4]. Stakeholders rated cost (mean 4.1) and skill gap (4.1) as the biggest barriers, which were correlated ($r = 0.62$), so training subsidies bundled with robot rentals would help [5, 14]. Digital-twin simulation indicated about 15% additional savings. Limitations are the single project and reliance on company data; future work should compare multiple projects and integrate real-time IoT monitoring [11, 12]. Projections for 2030 suggest masonry productivity growth of up to 5% annually, an injury rate of 5 per 100 workers, and cost overruns falling from 30% to 5% [11].

5. Challenges and Outcomes

Challenges: (i) *Set-up and site adaptability:* limited space required three extra days; the 30-ft reach limited use on curved walls, so 40% of the

exterior was laid by hand, and dust disturbed the laser system, requiring daily cleaning [7, 8]. (ii) *Weather*: winds of 25 mph and temperature swings (85°F day, 45°F night) made mortar uneven and required additives in the first week [8]. (iii) *Cost*: rental, training and calibration added about \$120,000 [7]. (iv) *Regulation*: OSHA required a person to watch the robot within 6 ft of workers; extra barriers and training delayed the start by a week [5, 14]. (v) *Skills and resistance*: experienced bricklayers initially feared job loss, early work was 20% slower than planned, and each worker needed 40 hours of training [5]. (vi) *Integration*: about 5% of the work (3,000 bricks) was redone at corners where robot and human work met [5, 7].

Outcomes: Table 11 matches each challenge with its solution and result. In addition, 12 close-call risks were prevented, daily checks and dust covers resolved early reliability problems, a local supplier partnership and GPS delivery stabilized mortar supply and cut logistics delay by a week [10], and operator acceptance rose to 85% with higher job satisfaction because of reduced strain [5].

Table 11
Challenge–outcome matrix

Challenge	Solution	Outcome	Impact
Set-up delay	Pre-site BIM planning, crane optimization	Set-up cut from 10 to 3 days	70% faster
Weather	Retarders, tarps, sensors	98% curing success	Defects –95%
High cost	Labor offset, reuse planning	\$590K net savings	ROI 390%
Regulation	Barriers, training	Zero violations	100% compliance
Skill gap	40-hour certified training	Efficiency 75% → 95%	+20 points
Integration	Hybrid workflow protocols	Rework hours –70%	Rework 5% → 2%

Contributions: This study (i) presents an adapted LCA for bricklaying robotics with primary stakeholder data ($n = 10$, $\alpha = 0.89$) [6, 14]; (ii) a stochastic model explaining 88% of productivity variance; (iii) statistical validation of the results; (iv) scenario analysis of hybrid human–robot teams [5]; and (v) actionable policy recommendations.

Policy recommendations: mandate robotic safety training in OSHA programs; provide tax incentives for robotic rental in public projects; update OSHA rules for working near robots by 2027; fund national robotics training centers by 2030; and pilot IoT-integrated robots in 2026 federal projects [12].

6. Conclusion

Robotic bricklaying addressed construction's major problems of safety risk, low productivity and labor shortage in the University Arts Building project: productivity rose by 500%, physical strain fell by 80%, injuries fell by 50% or more, and net savings reached \$590,000 with an ROI of 390% [4, 7, 13]. With good planning, training, technology improvement and policy support, early challenges (set-up difficulty, cost, regulation, skill gaps and workflow integration) can be overcome, especially as robot rental becomes easier and worker acceptance grows. Stakeholders ranked skill gaps as a major issue (4.1/5); training and visible benefits are the remedy, since operators reached 95% efficiency after training and experienced workers can move to higher-skilled roles rather than lose their jobs [5]. AI-based maintenance, IoT live tracking and smarter collaborative robots can bring further gains [11, 12]. The project shows that construction robotics is deployable now, particularly where labor is short, and can deliver better results for workers, projects and society [1, 9].

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