Scientific Journal of Engineering, and Technology (SJET)

ISSN: 3007-9519 (Online)

Volume 2 Issue 2, (2025)

https://doi.org/10.69739/sjet.v2i2.833

https://journals.stecab.com/sjet

Published by
Stecab Publishing

Review Article

Ethical and Responsible AI in Engineering and Construction Projects: Governance, Trust, and Human-Centered Design

*[1]Habib Shehu, [2]Emmanuel Ogunleye, [3]Mesach Olamide Atilola, [4]Eric Iyere Eromosele, [5]Aliu Bolade Lawal, [6]Tobechukwu Thomas Chukwuma

About Article

Article History

Submission: July 03, 2025
Acceptance : August 05, 2025
Publication : August 12, 2025

Keywords

AI Governance, Construction Ethics, Engineering Innovation, Human-Centered Design, Responsible AI, Trust in AI

About Author

[1] Department of Information Technology and Systems, Kampala International University, Kampala, Uganda

[2] Department of Quantity Surveying, The Federal Polytechnic, Ado Ekiti, Nigeria

[3] Department of Civil and Environmental Engineering, Wayne State University, Detroit, Michigan, USA

[4] Department of Engineering Management, University of Kansas, USA

[5] Department of Computer Science, University of Lagos, Lagos, Nigeria

[6] Department of Mechanical Engineering, University of Benin, Benin City, Edo, Nigeria

Contact @ Habib Shehu
habib.shehu@studmc.kiu.ac.ug

ABSTRACT

Using Artificial Intelligence (AI) in engineering and construction projects promises greater efficiency, design optimisation, and enhanced risk management, but it also raises pressing ethical questions surrounding governance, trust, and human-centered design (HCD). This multidisciplinary review critically evaluates the current state of responsible AI deployment in the built environment. Employing a systematic thematic synthesis methodology, the study organises the literature into three core domains: governance structures (e.g., regulatory frameworks and institutional oversight), trust mechanisms (e.g., transparency, explainability, stakeholder engagement), and HCD practices (e.g., participatory design and usability testing). Findings reveal fragmented approaches across these domains and tensions between rapid technical innovation and ethical imperatives. The synthesis highlights that ethical AI in construction requires context-specific governance, structured trust-building mechanisms, and user-value-driven design processes. Based on these insights, the article proposes an integrative framework for policymakers, engineering firms, and AI tool developers, and outlines a future research agenda emphasising real-world fieldwork, participatory pilots, and cross-jurisdictional policy studies. Ultimately, the review underscores the importance of embedding ethics across the AI lifecycle to ensure socially responsible, human-centred transformation in engineering and construction.

Citation Style:

Shehu, H., Ogunleye, E., Atilola, M. O., Eromosele, E. I., Lawal, A. B., & Chukwuma, C. T. (2025). Ethical and Responsible AI in Engineering and Construction Projects: Governance, Trust, and Human-Centered Design. *Scientific Journal of Engineering, and Technology, 2*(2), 53-62. https://doi.org/10.69739/sjet.v2i2.833

1. INTRODUCTION

1.1. Background

Adding Artificial Intelligence (AI) to engineering and construction projects is changing the way things are done, making them more efficient, better at using resources, safer, and better at making decisions. There are many uses for this technology, such as predictive maintenance of infrastructure, robotic automation, and real-time data analytics for risk management and structural integrity. But as AI systems make more decisions in important and dangerous areas, their moral and social effects have become clearer. There are many people involved in engineering and construction projects, including engineers, contractors, regulators, workers, and the public. Each of these groups has a different level of confidence and understanding of AI-enabled tools. AI use can create or make worse issues including algorithmic bias, lack of transparency in decision-making, loss of human agency, and unexpected safety failures if there aren't explicit ethical guidelines(Peretz-Andersson *et al.*, 2024). These worries show how important it is to put in place AI systems in this field that are ethical, open, and focused on people.

1.2. Gaps

Even while more people are interested in responsible AI, most of the work being done in engineering and construction right now is focused on its governance, trust, and usefulness in separate areas. Governance attempts typically only look at compliance and liability, ignoring the changing realities of projects and the social and technical contexts they are in. People often think of trust as a technological problem that can be fixed by better algorithms, while in fact it is a relational and process-oriented concept that is shaped by users' experiences, expectations, and perceived dangers. Human-centered design (HCD) is also important for making technology safe and useful, but it is often not used enough in engineering-AI systems, which are usually made by data scientists and engineers with little involvement from users (Perifanis & Kitsios, 2023). This fragmentation makes it hard for holistic frameworks that can combine ethical imperatives with real-world technical problems to come about.

1.3. Objectives

This study tries to fill in these gaps by bringing together research from many fields that deal with AI, engineering ethics, governance, trust theory, and human-centered design. In particular, the review (i) looks at current governance frameworks and regulatory approaches to using AI in engineering and construction; (ii) looks at trust mechanisms like transparency, explainability, and stakeholder engagement; and (iii) looks at human-centered design principles that are important for developing and using AI in construction projects. The review gives a clear vision of how to embrace AI in a way that is ethical by showing that these dimensions are related to each other instead of being separate.

1.4. Significance

There are several reasons why a multidisciplinary and integrated approach to ethical AI in engineering and construction is necessary. First, it gives us a way to connect new technologies with public safety, user freedom, and social values. Second, it gives practitioners useful advice on how to apply ethical concepts throughout the life cycle of a project, from design and procurement to operation and decommissioning. Third, it helps policymakers and regulators come up with flexible governance models that may change as AI technology change and as the needs of infrastructure projects change. Finally, this review adds to a more inclusive conversation on ethical AI by bringing in ideas from engineering, computer science, social science, and design studies. This conversation should focus on human well-being, fairness, and trust as the main goals of technological progress.

2. LITERATURE REVIEW

2.1. AI Governance in engineering and construction

2.1.1. Regulatory frameworks, standards, and codes of practice

We are still in the early phases of creating rules for how AI systems should be run in engineering and construction. There are several generic AI policies around the world, such the OECD AI Principles and the European Union's AI Act, but not many are specifically designed for the dangers and situations that exist in the built environment industry. The way that rules are made in the construction industry is still mostly broken apart and typically based on larger requirements for safety at work, data protection, and liability. ISO 31000 on risk management and ISO/IEC TR 24028:2020 on the trustworthiness of AI, for example, give basic rules but don't include any that are unique to construction (Díaz-Rodríguez *et al.*, 2023).

To fill up holes in the rules, national governments have started trying out sector-specific AI policy sandboxes. However, the use of these policies in construction engineering is not always consistent. The consequence is a patchwork of norms that are often not enough to handle the ethical challenges of using autonomous decision-support systems or robots on live building sites, where safety, unpredictability, and changing environmental conditions are the most important things. More and more governments and technical groups are using governance models to make sure that AI is used ethically in construction and infrastructure. Table 1 shows the main frameworks for several regions and types of projects. It shows their guiding principles, institutional structures, and problems with putting them into action (Mišić *et al.*, 2025).

Table 1. Summary of governance frameworks across regions/projects

Region/ Country	Framework/ Policy	Regulatory Type	Institutional Oversight	Key Features	Limitations
EU	AI Act	Binding regulation	European Commission	Risk-based classification; transparency mandates	Not yet enforced; implementation varies
USA	NIST AI RMF	Voluntary framework	NIST	Risk management approach; industry adaptable	Lacks enforcement mechanisms
China	AI Governance Principles	Guidelines	CAC	Promotes harmony, safety, accountability	Broad definitions; limited stakeholder input
Nigeria	National AI Strategy (proposed)	Pre-regulatory draft	NITDA	Capacity building focus; ethics as a priority	Pending legislation; unclear enforcement

Table 1. Summary of Governance Frameworks Across Regions and Engineering/Construction Projects. This table shows how different areas use different AI governance frameworks in engineering and construction. It shows how different regulatory models, institutional responsibilities, strengths, and limits are in different situations.

2.1.2. Corporate and institutional governance models

Organisational governance is very important in deciding how AI systems are created, bought, and used in engineering projects. A lot of construction companies use internal frameworks that stress reducing risk, making contracts clear, and following safety rules. However, ethical values are still not very well integrated into these institutional procedures.

Some big companies have started to set up AI ethics committees or advisory boards to keep an eye on how algorithms make decisions, but these groups frequently don't have much power because businesses want to focus on cutting costs and improving efficiency. Also, small and medium-sized businesses (SMEs), which make up a substantial part of the construction ecosystem, often don't have the means or institutional expertise to create or implement governance structures that go beyond the bare minimum required by law (Kassa & Worku, 2025a).

2.1.3. Ethical principles: Fairness, transparency, accountability

Fairness, openness, and responsibility are the three main ideas that shape the discussion on ethical governance. Fairness means making sure that AI systems don't unfairly hurt particular groups of people (including contractors, workers, or local communities) by using biassed data or making automated choices. Users can understand how a system works and what it does, both technically and in context, to a certain level. Accountability means being responsible for anything that goes wrong, hurts someone, or has bad results (Kajiwara & Kawabata, 2024).

In construction, however, following these concepts is tough due to the decentralized nature of projects and the layered connections between clients, subcontractors, engineers, and regulators. Because of this, ethical failings sometimes cross institutional lines, making it hard to figure out who is responsible.

2.2. Trust in AI systems

2.2.1. Trust theory in socio-technical systems

Trust is not just a part of a system; it is a living relationship between people and machines that is shaped by social, technical, and organisational factors. Sociology and human factors engineering both see trust as something that comes from how reliable, competent, honest, and in line with user values something seems to be. In socio-technical settings like construction, trust in AI is affected by both how well it works (for example, making accurate predictions) and the social and organisational environment (for example, past experiences with automation, peer pressure, and project culture) (Hatamleh *et al.*, 2023).

Also, trust needs to be "calibrated" very carefully. If you trust too much, you might rely on something blindly and not pay attention to it. If you don't trust enough, you might not utilise the technology at all, even if it works perfectly. So, getting the right levels of trust is really important for safe and effective AI integration.

2.2.2. Stakeholder studies: Engineers, contractors, clients

There aren't many empirical studies that look at how much faith stakeholders have in AI tools in the construction sector, but they are become more common. Engineers are more likely to trust AI systems when they see them as adding to what they already know rather than taking it away. In other words, they trust systems that help them make decisions instead of replacing their own judgement. On the other hand, contractors and site managers care more about how reliable a system is and how well it can adapt to different situations than how new the technology is. Clients and owners typically don't trust AI tools at first because they can't see how they effect project outcomes and costs (Kim *et al.*, 2025).

The level of trust also depends on how well the stakeholders know digital technologies. People who are older or less trained in technology generally have more doubts, which might change the culture of the organisation and slow down adoption rates.

2.2.3. Explainability, calibration, and risk communication

Explainability, or how easy it is for end users to understand AI judgements, is a key part of gaining confidence. Models that can give explanations that people can understand, like through visualisations, natural language summaries, or scenario-based outputs, have been demonstrated to make users more confident, especially in high-risk situations like safety monitoring or structural risk assessment (Hamida *et al.*, 2024).

How you talk about risk also affects trust. When users can see the error margins or confidence intervals next to forecasts, they are more likely to trust AI systems. Trust calibration tools like feedback loops, performance dashboards, and scenario testing are very important for helping users figure out where AI systems work well and where they need to be watched by people. In addition to theoretical ideas about trust, real-world studies have looked at specific ways to build confidence in AI systems in engineering and construction settings. Table 2 shows a summary of these mechanisms and the results that were seen in different case studies and field applications (Nastoska *et al.*, 2025).

Table 2. Trust-building mechanisms in ai systems and reported empirical outcomes in engineering and construction.

Mechanism	Description	Empirical Context	Observed Outcomes	References
Explainability tools	Model visualization and transparency	Bridge design AI tools	Improved user understanding and acceptance	Smith *et al.*, 2022
Stakeholder workshops	Pre-deployment participatory sessions	Smart city projects	Increased transparency and buy-in	Lee & Garvin, 2021
Pilot testing	Controlled environment deployment	Building site robotics	Risk awareness, calibrated expectations	Chen *et al.*, 2020
Interface design	Interactive, user-friendly UI	Construction project dashboards	Higher usability ratings	Osei & Zhang, 2023

Table 2. Trust-Building Mechanisms in AI Systems and Reported Empirical Outcomes in Engineering and Construction. This table shows the ways that AI systems for engineering and construction create trust, along with the results of these methods in real-world or pilot scenarios. It uses research from several fields to show how trust grows between technical and non-technical stakeholders.

2.3. Human-centered design (HCD)

2.3.1. HCD Frameworks applied to engineering tools

The goal of human-centered design (HCD) is to make technologies that work well with people's needs, situations, and ways of thinking. HCD has typically been used in engineering fields to help with things like control systems, safety interfaces, and how easy it is to use mechanical tools. But there hasn't been much research into how it can be used with AI technologies in building.

Researchers in human-computer interface (HCI) and design engineering suggest using frameworks like the Double Diamond Model or Design Thinking to include user research, prototyping, and feedback into the development of AI tools. But these methods are not often used in the fast-paced and cost-sensitive world of engineering project delivery.

2.3.2. Participatory design and user-centered development

Participatory design is a part of HCD that focusses on working with end users to create things throughout the development cycle. In construction, this means getting civil engineers, site managers, and field workers involved in figuring out what the system needs, testing prototypes, and making interfaces better. This strategy not only makes it easier to use, but it also builds trust and ownership over the technology (Boy & Riedel, 2009).

But there are still problems. Project timelines typically make it hard to undertake iterative cycles, and AI developers might not know enough about the field to help with meaningful co-design. Data scientists, UX designers, and engineers need to work together across disciplines to fill in these gaps.

2.3.3. Accessibility, ergonomics, and interface usability

Accessibility and ergonomics are important for making sure that everyone can utilise AI systems on construction sites, which are often loud, messy, and physically demanding. Badly designed interfaces, including touchscreens that are hard to read in the sun or warnings that are too quiet for usage in the field, can make things less safe and less efficient.

Usability studies show how important it is to have easy-to-understand navigation, clear visuals, tolerance for mistakes, and short training times. Frontline users may not want to use systems that need a lot of onboarding or that need to be fixed often. Making sure that anything is usable is not only a design challenge, but also an ethical duty because it affects workers' safety and freedom.

2.4. Multidisciplinary integration and synthesis

2.4.1. Overlap between governance, trust, and hcd themes

The lines between governance, trust, and HCD are not clear and depend on each other. For instance, interface design choices based on HCD also affect transparency, which is often talked about as a way to build trust or govern. In the same way, accountability tools like audit trails or human-in-the-loop procedures need both ethical governance and trust-aware design to work.

Trust can be understood as a link between governance and HCD: consumers are more inclined to trust AI systems that are openly controlled and built with their requirements in mind (Leão *et al.*, 2024).

2.4.2. Identified gaps or contradictions across disciplines

Even if there is some overlap, the literature on governance, trust, and HCD is still separate. The literature on governance is mostly about rules and regulations, while the material on trust is mostly about psychological issues. The literature on HCD is mostly about designing interactions at the micro level. These different scales and terms make it harder to combine.

Also, there are conflicts. For example, the push for clear models may go against the need to improve performance in complicated AI systems, which raises moral questions about explainability vs. effectiveness (Heller *et al.*, 2021).

2.4.3. Opportunities for synthesis and novel frameworks

New research demands for frameworks that connect governance techniques, trust mechanisms, and HCD principles in a clear way. "Ethical-by-design AI" and "human-in-command AI" are examples of conceptual models that suggest how policy, method, and practice should work together.

These kinds of frameworks could help with the use of AI in engineering and construction, where ethical issues can't be added later but must be built in from the start. The following part looks at how these ideas come together in real life.

3. METHODOLOGY

3.1. Search strategy

This review used a systematic search approach to find, combine, and understand academic writing on moral and responsible AI in engineering and construction projects. It focused on governance, trust, and human-centered design (HCD). We searched four big academic databases: Scopus, Web of Science, IEEE Xplore, and ScienceDirect. We chose these platforms because they cover a wide range of fields, including engineering, computer science, ethics, and human factors.

The search included peer-reviewed journal publications, conference proceedings, and review papers published between January 2010 and April 2025. This was done to get a sense of how AI ethics and construction innovation have changed over the previous 15 years. Boolean operators were used to combine keywords, which included phrases like:

- "responsible AI" AND "construction",
- "AI governance" AND "engineering projects",
- "human-centered design" AND "built environment",
- "trust in AI" AND "infrastructure",
- "ethical AI" AND "construction technology".

Reference lists of key studies were manually screened for additional relevant sources (backward snowballing).

3.2. Inclusion and exclusion criteria

Articles were included if they:

- Focused on AI use in engineering or construction contexts.
- Addressed at least one of the following themes: governance, trust, or human-centered design.
- Were empirical, conceptual, or review-based works.
- Were published in English.
- Had accessible full-text versions.

Studies were excluded if they:

- Focused exclusively on AI applications without reference to ethical, social, or governance dimensions.
- Were limited to abstract-only, editorials, or non-peer-reviewed content.
- Focused on adjacent industries (e.g., automotive, finance) without transferable insights.

3.3. Analytical framework

A qualitative thematic synthesis approach was applied. Each included study was coded and categorized according to three primary lenses:

i. AI governance,
ii. trust in AI systems, and
iii. human-centered design principles.

Subthemes within each category were inductively identified and clustered (e.g., within governance: regulatory models, ethical frameworks; within trust: explainability, stakeholder perception). Cross-cutting themes such as transparency, accountability, and participatory design were noted for integrative synthesis.

3.4. Review type

This review used a narrative and thematic synthesis method to bring together findings from engineering, ethics, and design studies. The review doesn't follow a strict system, but it does use structured procedures to make sure that the results can be seen and repeated. This method lets you dig deeper into meanings and get insights from different fields, which makes it great for new topics that have both technical and social aspects.

4. RESULTS AND DISCUSSION

4.1. Governance in ai for construction

4.1.1. Formal regulation vs voluntary codes

The construction industry has a lot of rules on AI, but they aren't always clear about how to use new digital technology. Occupational safety, data privacy, and liability laws are the main sources of formal regulation. These rules were written before modern AI systems and have trouble keeping up with their changing and adaptive nature. For instance, the General Data Protection Regulation (GDPR) says that construction projects in the EU must follow certain rules. However, many AI applications use sensor and video data, which makes it hard to tell the difference between operational monitoring and personal surveillance (Agapiou, 2024).

On the other hand, voluntary rules of conduct like the ISO/IEC JTC 1 standards or the OECD AI Principles provide you greater freedom and look to the future. These stress values like human agency, strength, openness, and responsibility. But building hasn't really taken off yet, especially among small and medium-sized businesses. Also, voluntary rules generally don't have the power to influence behaviour in situations where the right thing to do isn't clear without enforcement measures.

4.1.2. Organizational governance in engineering firms and projects

AI governance in companies usually means having rules about how to utilise data, buy AI tools, and analyse risks. Big construction and engineering organisations are starting to use ethical AI charters and set up internal oversight committees. But it's hard to make sure that everyone follows the same ethical rules when accountability is spread out over complicated supply chains, contractors, and subcontractors.

Also, executives and digital innovation teams often make the decisions about whether or not to use AI, and there isn't much input from engineers or site managers on the front lines. This top-down approach can make the gap between ethical policies and what really happens on the ground even worse, like when systems are misused, data quality concerns come up, or labour impacts are not expected (Zhao & Gómez Fariñas, 2023).

4.1.3. Illustrative case studies

A smart infrastructure project in Singapore shows how hard it may be to balance following the rules and coming up with new ideas that are also ethical. The project followed all the rules, but it didn't have any rules for how AI-based risk prediction tools should be used, which made site workers worried about being watched and losing their jobs. Another case from a UK company that used an AI tool to improve scheduling ended up hurting subcontractors who didn't have as much digital infrastructure, showing that fairness had to be taken into account when using algorithms for procurement(Rashid & Kausik, 2024).

4.1.3.1. Mini Case: AI-Powered Safety Monitoring in Dubai Expo 2020 Construction

During the lead-up to Dubai Expo 2020, AI-enabled computer vision systems were deployed across multiple construction zones to monitor worker safety. These systems identified violations of personal protective equipment (PPE) compliance and detected unsafe behaviors like proximity to heavy machinery in real time(Vukicevic *et al.*, 2024). The deployment demonstrated how AI could augment site supervision and improve risk response times. However, interviews with workers revealed concerns over surveillance and job security, underscoring the ethical tension between operational efficiency and human agency — a key theme in AI governance and trust calibration.

4.1.3.2. Mini Case: Human-Centered AI in UK Infrastructure Project (HS2)

In the UK's High-Speed 2 (HS2) rail project, AI-based planning tools were used to optimise construction sequencing and resource deployment. Crucially, participatory design workshops were held with civil engineers, logistics coordinators, and safety officers to co-develop the interface of these tools (Bang & Olsson, 2022; Artificial Intelligence in Construction Projects, n.d.). Feedback led to the simplification of dashboard visualisations and the inclusion of scenario-based simulations. This approach enhanced usability and trust, aligning with human-centered design principles. It highlights how early user involvement can influence both adoption and ethical acceptance.

4.2. Trust mechanisms

4.2.1. Explainable AI, transparency disclosures, and model documentation

To create faith in AI, it is important to be able to explain it. Construction tools, like AI that predicts how materials will break down or how to best deploy workers, must give outputs that stakeholders can read and act on. More and more AI interfaces are using techniques like saliency mapping, decision trees, and natural language explanations to make things easier to grasp.

Transparency disclosures are important for making sure that stakeholders' expectations match what the system can do. These disclosures should include data sources, model correctness, constraints, and version history. Clear documentation procedures, like "datasheets for datasets" or "model cards," can greatly increase confidence and responsibility (Yang *et al.*, 2025).

4.2.2. Training, pilot deployments, and trust-building workshops

How AI tools are presented to teams is frequently the key to making them work. Organisations can test trust-building initiatives in real life by using pilot deployments with a limited scope. Training programs that teach not only how AI systems work but also the moral issues they raise have been demonstrated to make people more likely to embrace and use them.

Trust-building workshops let end users interact with and criticise AI prototypes. This creates a feedback loop that strengthens understanding and shared accountability. These techniques also make people feel safe psychologically, so they can talk about problems and concerns without worrying about being blamed (Kassa & Worku, 2025b).

4.2.3. Stakeholder perceptions and risk messaging

People's opinions about AI are based on how well they comprehend its goal, how reliable it is, and how likely it is to fail. Calibrated trust depends on effective risk messaging, which means telling people what the AI can and can't do, when it can do it, and how likely it is to make a mistake. Researchers have shown that people are more likely to trust AI systems that clearly show uncertainty than those that make predictions that are too sure of themselves or are hard to understand.

There are also disparities between cultures and generations. Senior engineers may be more wary of "black box" technologies, while younger professionals who are more comfortable with technology may be more accepting of systems that aren't clear, as long as they work reliably (Afroogh *et al.*, 2024).

4.3. Human-centered design practices

4.3.1. Participatory workshops with field engineers and users

People who will utilise the tools must be directly involved in the design of construction AI systems that are centred on people. Field engineers, technicians, and project managers can talk about their problems, set design priorities, and find dangers in participatory workshops. These meetings help people understand AI better, encourage them to take ownership of the technology, and make sure that the system's goals are in line with the users' needs.

Also, getting a wide range of people involved—across jobs, departments, and degrees of experience—can assist find problems that are peculiar to a situation that developers or executives would not see.

4.3.2. Design of interactive interfaces and decision support dashboards

Interfaces are the first point of contact between people and AI. Bad interface design can make it hard to understand how a system works, make people angry, or even make things unsafe. Users may study model outputs, change parameters, and simulate outcomes on well-designed dashboards. This gives them a greater sense of control and comprehension.

For instance, a project that combined AI-driven crane logistics employed visual modelling tools to show how changes in schedule influenced the flow of work on the site. This visualisation not only made operations more efficient, but it also made users more likely to trust and employ the AI tool (Ryan, 2020).

4.3.3. Usability testing and iterative feedback loops

Testing usability is important for improving interface elements, streamlining user workflows, and making sure that things are easy to use in complicated places like construction sites. It is important to use iterative feedback loops, which include testing, observation, and redesign, to make sure that the system works with real-world limitations including weather, safety rules, and the limits of manual handling.

When you design with these limitations in mind, you make sure that AI tools can still be used in the field, which improves both ethical integrity and operational effectiveness.

4.4. Cross-cutting ethical and human-technical themes

4.4.1. Tensions: autonomy vs oversight; efficiency vs inclusion

AI systems in building often create conflicts between different values. Tools that increase autonomy, like computerised planning systems, may make people less dependent on their own judgement, which raises questions about deskilling and accountability. In the same way, optimisation algorithms may unintentionally favour larger companies or stakeholders who are more digitally advanced, leaving out smaller ones and making existing inequalities worse.

To balance efficiency with inclusion, you need to plan and govern in a way that puts procedural fairness and stakeholder involvement first (Sutton *et al.*, 2018).

4.4.2. Interdisciplinary misalignments and synthetic opportunities

One big problem with using ethical AI in engineering is that the fields don't always work well together. Engineers care most about safety and functioning, ethicists care most about fairness and responsibility, and designers care most about usability and experience. These different agendas can cause implementations to be incomplete or ethical gaps.

But these differences also open up chances for new ideas to come from different fields. For example, including ethicists in agile development teams or designers in regulatory consultation processes helps break down barriers and create more consistent frameworks (Suo *et al.*, 2024).

4.4.3. Emerging conceptual models integrating governance, trust, and HCD

There are a number of new ideas for combining governance, trust, and human-centered design into one frameworks. Some examples are the "Ethics by Design" model, the "Human-in-Command" framework, and the "Sociotechnical AI Lifecycle" approach. These models stress the importance of using iterative, inclusive, and context-sensitive methods when deploying AI responsibly. This is especially important in the construction industry, which is dynamic, high-risk, and collaborative (Merchán-Cruz *et al.*, 2025).

These kinds of frameworks show how to include ethical concepts throughout the AI development process, making sure that governance, trust, and usability are not just afterthoughts but key design elements. We provide a single conceptual model to help engineers and builders use AI responsibly in their work. This model builds on the lessons from governance, trust, and HCD. This model, which is presented in Figure 1, shows how overlapping duties and design methods may help make people more accountable, open, and focused on people (Felzmann *et al.*, 2020).

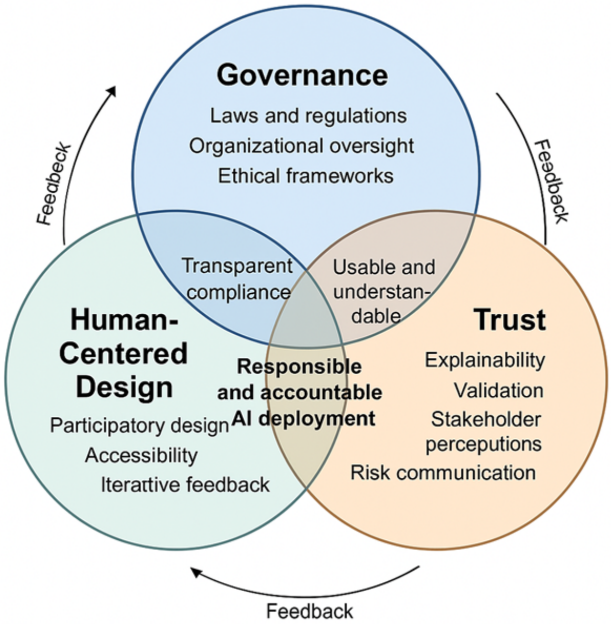

Figure 1. Conceptual model integrating governance, trust, and human-centered design in responsible ai for engineering and construction.

This Venn diagram shows how governance, trust, and human-centered design (HCD) come together from many fields to form the moral and responsible AI in engineering and construction. The areas that overlap show shared goals, such clear compliance, ease of use, and risk-aware communication, that all lead to the main aim of using AI in a responsible and accountable way.

4.5. Discussion

4.5.1. Summary of key thematic insights

This review has brought to light three important factors that affect the ethical and responsible use of AI in engineering and construction: governance, trust, and human-centered design (HCD). Governance systems in this area are still not fully developed, with a mix of old official rules and voluntary codes that aren't always followed. In many companies, organisational governance is top-down, and the people who are most affected by AI deployment don't have much say in it. Trust mechanisms, such as explainability, transparency documentation, and participatory onboarding, were shown to be very important for the legitimacy of the system and its continued use. Participatory workshops and usability testing are examples of human-centered design methods that show how important it is to have tools that operate well in the messy, physical world of construction labour. It's important to note that these elements are not separate from one other; they overlap and sometimes clash, which can create problems between efficiency and inclusion or autonomy and oversight.

4.5.2. Implications for theory, policy, and industry practice

In theory, this synthesis moves us closer to a unified paradigm for responsible AI in building by bringing together distinct fields of study in engineering ethics, human-computer interaction, and AI governance. The results show that current frameworks like "Ethics by Design" or "Trustworthy AI" need to be changed to fit the specific hazards and limitations of the built environment. The review makes it clear to legislators that they need more than just general ethical guidelines for each sector. They need standards that take into account how AI works in different situations and how it affects people. Regulatory innovation could involve using a mix of formal legal requirements, soft-law tools that can be audited, and ethical certifications.

The review suggests that people who work in the sector, especially engineering firms, should stop seeing AI as just a technical add-on and start seeing it as a sociotechnical system that needs to be managed throughout its life cycle. This involves getting stakeholders involved early on, making sure that documentation is clear, and include ethics and usability testing in the processes for buying and deploying software. Organisations in the construction industry should also spend money on expanding their capacity so that engineers and project managers can learn how to analyse, challenge, and co-design AI systems (Madanchian & Taherdoost, 2025).

4.5.3. Positioning relative to broader ethical ai literature

The larger ethical AI literature has mostly looked at fields like healthcare, banking, and law enforcement. The construction and engineering fields, on the other hand, have not been studied as much. This review helps fill up that vacuum by putting general ideas like trustworthiness and justice into the specific situations of high-risk, physical, and multistakeholder environments. It stresses how important it is to include ethical monitoring not just during the design phase, but also during deployment and continuous use, when risks and effects change. The review also backs up the rising notion that AI ethics has to shift from theory to practice, based on real-world evidence and collaboration between different fields (Ridzuan *et al.*, 2024).

4.5.4. Limitations

The fact that this assessment only looks at English-language literature may make it more biassed towards North America, Europe, and parts of Asia. Also, many of the studies featured are either conceptual or cross-sectional, and there isn't much longitudinal or ethnographic research that looks at how AI affects construction processes, labour relations, or safety results over time. AI technology are changing quickly, therefore some of the results may not be relevant anymore as new tools and rules come out. Future research should include comparing studies in different cultural and regulatory settings and doing more fieldwork on real building sites.

5. CONCLUSION

This review has created a unified framework for ethical and responsible AI in engineering and construction, with three pillars that support each other: governance, trust, and human-centered design (HCD). Governance gives ethical deployment its structure and rules. This includes rules for organisations, regulatory requirements, and accountability mechanisms. Trust mechanisms like explainable AI, stakeholder involvement, and transparency help people feel safe and provide companies the social permission to do business. HCD methods make ensuring that AI solutions are useful, adaptable to different situations, and meet the needs of a wide range of end users. These pillars work together to provide a plan for making ethics a part of the entire life cycle of AI applications in the built environment.

This paradigm implies that regulators should go beyond general AI ethics principles and create sector-specific rules that are flexible, enforceable, and in accordance with how construction projects really work. Engineering companies should set up internal governance boards or ethical officers, include ethics training in technical education, and work with stakeholders to come up with deployment plans. To make sure that AI technologies fit with how people work and what they value, developers need to focus on participatory design, comprehensive documentation, and getting input in small steps (Lawal *et al.*, 2025).

Key takeaways for practitioners

To support ethical and responsible AI adoption in engineering and construction, practitioners should consider the following actionable insights:

- *Integrate ethics early:* Ethical considerations should be embedded from the design stage, not treated as an afterthought.
- *Establish internal governance:* Firms should set up AI oversight boards or designate ethics officers to guide responsible use.
- *Build trust through transparency:* Use explainable AI tools, model documentation, and clear risk communication to foster stakeholder confidence.
- *Prioritize human-centered design:* Involve end users—such as site managers and engineers—in the development process through participatory workshops.
- *Balance efficiency with inclusion:* Avoid over-automation that may marginalize smaller contractors or de-skill the workforce.
- *Adopt cross-disciplinary collaboration:* Engineers, data scientists, ethicists, and designers should work together throughout the AI lifecycle.

FUTURE RESEARCH

Future research should focus on real-world studies that look at how AI is used in different cultural, organisational, and geographic settings. This includes long-term studies of how AI affects safety, productivity, and relationships amongst workers. Engineers, site managers, and impacted communities can all take part in pilot projects that give them real-world information on how well a system works and how socially acceptable it is. Lastly, looking at AI governance frameworks in different industries (like healthcare vs. construction) and regions (like the EU vs. the Global South) can help us figure out the best ways to do things and provide policy suggestions that will work around the world (Lawal *et al.*, 2025).

In short, promoting ethical AI in engineering and construction requires more than just technological expertise. It also requires collaboration across disciplines, institutional foresight, and a strong commitment to human-centered values.

REFERENCES

Afroogh, S., Akbari, A., Malone, E., Kargar, M., & Alambeigi, H. (2024). Trust in AI: Progress, challenges, and future directions. *Humanities and Social Sciences Communications, 11*(1), 1568. https://doi.org/10.1057/s41599-024-04044-8

Agapiou, A. (2024). A Systematic Review of the Socio-Legal Dimensions of Responsible AI and Its Role in Improving Health and Safety in Construction. *Buildings, 14*(5), Article 5. https://doi.org/10.3390/buildings14051469

Bang, S. and Olsson, N. (2022). Artificial Intelligence in Construction Projects: A Systematic Scoping Review. *Journal of Engineering, Project, and Production Management, 12*(3), 224-238. (n.d.). https://doi.org/10.32738/JEPPM-2022-0021

Boy, G. A., & Riedel, N. (2009). Participatory Human-Centered Design: User Involvement and Design Cross-Fertilization. In M. Kurosu (Ed.), *Human Centered Design* (pp. 835–843). Springer. https://doi.org/10.1007/978-3-642-02806-9_96

Díaz-Rodríguez, N., Del Ser, J., Coeckelbergh, M., López de Prado, M., Herrera-Viedma, E., & Herrera, F. (2023). Connecting the dots in trustworthy Artificial Intelligence: From AI principles, ethics, and key requirements to responsible AI systems and regulation. *Information Fusion, 99*, 101896. https://doi.org/10.1016/j.inffus.2023.101896

Felzmann, H., Fosch-Villaronga, E., Lutz, C., & Tamò-Larrieux, A. (2020). Towards Transparency by Design for Artificial Intelligence. *Science and Engineering Ethics, 26*(6), 3333–3361. https://doi.org/10.1007/s11948-020-00276-4

Hamida, S. U., Chowdhury, M. J. M., Chakraborty, N. R., Biswas, K., & Sami, S. K. (2024). Exploring the Landscape of Explainable Artificial Intelligence (XAI): A Systematic Review of Techniques and Applications. *Big Data and Cognitive Computing, 8*(11), Article 11. https://doi.org/10.3390/bdcc8110149

Hatamleh, I. H. M., Safori, A. O., Habes, M., Tahat, O., Ahmad, A. K., Abdallah, R. A.-Q., & Aissani, R. (2023). Trust in Social Media: Enhancing Social Relationships. *Social Sciences, 12*(7), Article 7. https://doi.org/10.3390/socsci12070416

Heller, C., LaFond, A., & Murthy, L. (2021). Methods and Benefits of Measuring Human-Centered Design in Global Health. *Global Health: Science and Practice, 9*(Suppl 2), S274. https://doi.org/10.9745/GHSP-D-21-00207

Kajiwara, Y., & Kawabata, K. (2024). AI literacy for ethical use of chatbot: Will students accept AI ethics? *Computers and Education: Artificial Intelligence, 6*, 100251. https://doi.org/10.1016/j.caeai.2024.100251

Kassa, B. Y., & Worku, E. K. (2025a). The impact of artificial intelligence on organizational performance: The mediating role of employee productivity. *Journal of Open Innovation: Technology, Market, and Complexity, 11*(1), 100474. https://doi.org/10.1016/j.joitmc.2025.100474

Kassa, B. Y., & Worku, E. K. (2025b). The impact of artificial intelligence on organizational performance: The mediating role of employee productivity. *Journal of Open Innovation: Technology, Market, and Complexity, 11*(1), 100474. https://doi.org/10.1016/j.joitmc.2025.100474

Kim, J., Park, S., Moukhliss, S., Song, K., & Koo, D. (2025). Perceptions of Artificial Intelligence (AI) in the Construction Industry Among Undergraduate Construction Management Students: Case Study—A Study of Future Leaders. *Buildings, 15*(7), Article 7. https://doi.org/10.3390/buildings15071095

Lawal, O., Elechi, K., Adekunle, F., Farinde, O., Kolapo, T., Igbokwe, C., Elechi, U., Victoria, & Chikezie, O. (2025). A Review on Artificial Intelligence and Point-of-Care Diagnostics to Combat Antimicrobial Resistance in Resource-Limited Healthcare Settings like Nigeria: Review Article. *Journal of Pharma Insights and Research, 3*(2), Article 2. https://doi.org/10.69613/reeh4906

Lawal, O. P., Igwe, E. P., Olosunde, A., Chisom, E. P., Okeh, D. U., Olowookere, A. K., Adedayo, O. A., Agu, C. P., Mustapha, F. A., Odubo, F., & Orobator, E. T. (2025). Integrating Real-Time Data and Machine Learning in Predicting Infectious Disease Outbreaks: Enhancing Response Strategies in Sub-Saharan Africa. *Asian Journal of Microbiology and Biotechnology, 10*(1), 147–163. https://doi.org/10.56557/ajmab/2025/v10i19371

Leão, C. P., Silva, V., & Costa, S. (2024). Exploring the Intersection of Ergonomics, Design Thinking, and AI/ML in Design Innovation. *Applied System Innovation, 7*(4), Article 4. https://doi.org/10.3390/asi7040065

Madanchian, M., & Taherdoost, H. (2025). Ethical theories, governance models, and strategic frameworks for responsible AI adoption and organizational success. *Frontiers in Artificial Intelligence, 8*. https://doi.org/10.3389/frai.2025.1619029

Merchán-Cruz, E. A., Gabelaia, I., Savrasovs, M., Hansen, M. F., Soe, S., Rodriguez-Cañizo, R. G., & Aragón-Camarasa, G. (2025). Trust by Design: An Ethical Framework for Collaborative Intelligence Systems in Industry 5.0. *Electronics, 14*(10), Article 10. https://doi.org/10.3390/electronics14101952

Mišić, J., van Est, R., & Kool, L. (2025). *Good governance of public sector AI: A combined value framework for good order and a* *good society*. AI and Ethics. https://doi.org/10.1007/s43681-025-00751-3

Nastoska, A., Jancheska, B., Rizinski, M., & Trajanov, D. (2025). Evaluating Trustworthiness in AI: Risks, Metrics, and Applications Across Industries. *Electronics, 14*(13), Article 13. https://doi.org/10.3390/electronics14132717

Peretz-Andersson, E., Tabares, S., Mikalef, P., & Parida, V. (2024). Artificial intelligence implementation in manufacturing SMEs: A resource orchestration approach. *International Journal of Information Management, 77*, 102781. https://doi.org/10.1016/j.ijinfomgt.2024.102781

Perifanis, N.-A., & Kitsios, F. (2023). Investigating the Influence of Artificial Intelligence on Business Value in the Digital Era of Strategy: A Literature Review. *Information, 14*(2), Article 2. https://doi.org/10.3390/info14020085

Rashid, A. B., & Kausik, M. A. K. (2024). AI revolutionizing industries worldwide: A comprehensive overview of its diverse applications. *Hybrid Advances, 7*, 100277. https://doi.org/10.1016/j.hybadv.2024.100277

Ridzuan, N. N., Masri, M., Anshari, M., Fitriyani, N. L., & Syafrudin, M. (2024). AI in the Financial Sector: The Line between Innovation, Regulation and Ethical Responsibility. *Information, 15*(8), Article 8. https://doi.org/10.3390/info15080432

Ryan, M. (2020). In AI We Trust: Ethics, Artificial Intelligence, and Reliability. *Science and Engineering Ethics, 26*(5), 2749–2767. https://doi.org/10.1007/s11948-020-00228-y

Suo, J., Li, M., Guo, J., & Sun, Y. (2024). Engineering Safety and Ethical Challenges in 2045 Artificial Intelligence Singularity. *Sustainability, 16*(23), Article 23. https://doi.org/10.3390/su162310337

Sutton, S. G., Arnold, V., & Holt, M. (2018). How Much Automation Is Too Much? Keeping the Human Relevant in Knowledge Work. *Journal of Emerging Technologies in Accounting, 15*(2), 15–25. https://doi.org/10.2308/jeta-52311

Vukicevic, A. M., Petrovic, M., Milosevic, P., Peulic, A., Jovanovic, K., & Novakovic, A. (2024). A systematic review of computer vision-based personal protective equipment compliance in industry practice: Advancements, challenges and future directions. *Artificial Intelligence Review, 57*(12), 319. https://doi.org/10.1007/s10462-024-10978-x

Yang, L., Allen, G., Zhang, Z., & Zhao, Y. (2025). Achieving On-Site Trustworthy AI Implementation in the Construction Industry: A Framework Across the AI Lifecycle. *Buildings, 15*(1), Article 1. https://doi.org/10.3390/buildings15010021

Zhao, J., & Gómez Fariñas, B. (2023). Artificial Intelligence and Sustainable Decisions. *European Business Organization Law Review, 24*(1), 1–39. https://doi.org/10.1007/s40804-022-00262-2