

Theoretical and Applied Technological Science Review

Volume: 4 Issue: 3 Year: 2026

ISSN-2958-7824



Received: 20 May 2026

Revised: 25 June 2026

Accepted: 30 June 2026

DOI: <https://doi.org/10.64907/xkmf.v4i3.tatscr.2>

Research Article

Architectural Robotics and Sustainable Interiors: An Ethnographic Study of Contemporary Practice

Md. Sabbir Ahammed¹; Kazi Abdul Mannan²

¹ Department of Interior
Architecture,

²Department of Business
Administration
Shanto-Mariam University of
Creative Technology
Dhaka, Bangladesh

*Correspondence

Md. Sabbir Ahammed

Email:

sabbirtonmoy639@gmail.com

ABSTRACT

The integration of architectural robotics into interior design represents a transformative shift toward adaptive, efficient, and sustainable built environments. This study investigates the role of robotic systems in advancing sustainable interiors through an ethnographic, qualitative analysis based on secondary data, including scholarly literature, case studies, and industry reports. Grounded in Actor-Network Theory, Sustainable Design Theory, and Human-Technology Interaction, the research explores how robotic technologies influence material efficiency, energy optimisation, spatial adaptability, and user engagement. The findings reveal that architectural robotics enhances sustainability by enabling precision fabrication, responsive environmental systems, and reconfigurable spatial solutions. At the same time, the study identifies critical socio-cultural and ethical considerations, including user agency, accessibility, and lifecycle environmental impacts. The research demonstrates that robotic interiors function as complex socio-technical systems where human and non-human actors interact to shape sustainable outcomes. By offering a holistic framework, this study contributes to the discourse on smart environments and emphasises the need for interdisciplinary collaboration in the design of future interior spaces.

Keywords: architectural robotics; sustainable interiors; ethnography; adaptive environments; human-technology interaction; smart design; socio-technical systems

Copyright: 2026 by the authors. Licensee KMF Publishers (www.kmf-publishers.com). This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The convergence of digital technologies with the built environment has significantly transformed architectural and interior design practices in the twenty-first century. Among these technological innovations, architectural robotics has emerged as a critical domain that integrates computational design, automation, and responsive systems into spatial production and operation (Bock & Linner, 2015). Architectural robotics extends beyond industrial automation by embedding intelligent, adaptive, and often autonomous systems into buildings and interiors, thereby enabling dynamic interaction between users, environments, and technological infrastructures (Gramazio et al., 2014). Concurrently, the growing urgency of environmental sustainability has reshaped design priorities, particularly within interior architecture, where material consumption, energy use, and occupant well-being are central concerns (Kibert, 2016).

Interior spaces are increasingly recognised as key sites for sustainability interventions, given that people spend a substantial portion of their lives indoors. Sustainable interior design emphasises not only environmental efficiency but also social and cultural dimensions of space, including comfort, health, and behavioural adaptation (Pile & Gura, 2014). Within this context, architectural robotics presents new opportunities to address sustainability challenges through precision, adaptability, and real-time responsiveness. For example, robotic systems can optimise lighting and thermal conditions, reduce material waste

during fabrication, and enable reconfigurable spaces that extend the lifecycle of interior environments (Kolarevic & Parlac, 2015).

Despite these technological advancements, the integration of robotics into interior design is not merely a technical evolution but also a socio-cultural transformation. The presence of robotic systems in everyday environments alters how users interact with space, how designers conceptualise interiors, and how sustainability is understood and practised. This shift necessitates a deeper exploration of the human, cultural, and organisational dimensions of architectural robotics, which are often overlooked in predominantly technical or engineering-focused studies (Pink et al., 2016).

Ethnography offers a valuable methodological lens for examining these dimensions, as it emphasises the lived experiences, practices, and meanings associated with technological adoption. In design research, ethnographic approaches have been increasingly employed to understand how users engage with smart technologies and how these interactions shape spatial practices (Pink et al., 2016). By adopting an ethnographic perspective, this study seeks to move beyond purely functional analyses of architectural robotics and instead explore how these systems are embedded within broader networks of human and non-human actors.

The concept of sustainability itself has evolved from a focus on environmental conservation to a more holistic framework that encompasses economic viability, social equity, and cultural relevance (McDonough & Braungart, 2002). Architectural robotics

aligns with this expanded understanding by enabling not only resource efficiency but also adaptive and user-centred environments. However, the deployment of robotic systems also raises critical questions regarding accessibility, ethical implications, and long-term environmental impacts, particularly in relation to energy consumption, material sourcing, and technological obsolescence (Menges & Reichert, 2015).

Furthermore, the adoption of architectural robotics varies across different cultural and geographic contexts, reflecting diverse technological infrastructures, economic conditions, and design traditions. In emerging economies, for instance, the integration of advanced robotic systems may be constrained by cost and technical expertise, yet it also presents opportunities for leapfrogging traditional development models and adopting more sustainable practices. Understanding these contextual dynamics is essential for developing inclusive and scalable design strategies.

This study aims to investigate the intersection of architectural robotics and sustainable interiors through an ethnographic analysis of contemporary practices. Specifically, it seeks to address the following research questions:

- How do architectural robotic systems contribute to sustainability in interior design?
- In what ways do users and designers interact with robotic environments?
- What socio-cultural implications arise from the integration of robotics into interior spaces?

To answer these questions, the study employs a qualitative research methodology based on secondary data sources, including academic literature, design case studies, and industry reports. Through thematic analysis, the research identifies key patterns and insights related to sustainability, human-technology interaction, and cultural transformation.

By situating architectural robotics within an ethnographic and theoretical framework, this study contributes to the growing body of knowledge on smart environments and sustainable design. It highlights the need for interdisciplinary approaches that integrate technical innovation with social and cultural understanding, ultimately supporting the development of more responsive, inclusive, and sustainable interior environments.

2. Literature Review

Architectural robotics represents a rapidly evolving field that integrates robotics, computation, and architectural design to create responsive and adaptive built environments. Unlike traditional construction automation, which focuses primarily on efficiency and productivity, architectural robotics emphasises interaction, flexibility, and design innovation (Bock & Linner, 2015). This paradigm shift is closely linked to advancements in digital fabrication, parametric design, and cyber-physical systems.

Gramazio et al. (2014) describe architectural robotics as a transformative force that redefines the relationship between design and production. Robotic fabrication enables architects to realise complex geometries with

high precision, reducing material waste and enabling customisation at scale. These capabilities are particularly relevant to interior design, where bespoke solutions and spatial optimisation are critical.

In addition to fabrication, architectural robotics encompasses kinetic and responsive systems that allow buildings and interiors to adapt to changing conditions. Menges and Reichert (2015) highlight the concept of “embedded responsiveness,” where materials and structures are designed to respond dynamically to environmental stimuli. This approach aligns with broader trends in smart architecture, where sensors, actuators, and control systems enable real-time adaptation.

However, the implementation of architectural robotics also presents challenges, including high costs, technical complexity, and the need for interdisciplinary collaboration. These challenges underscore the importance of integrating technological innovation with practical and cultural considerations.

2.1 Sustainable Interior Design: Principles and Practices

Sustainable interior design is grounded in the principles of environmental responsibility, resource efficiency, and occupant well-being. Kibert (2016) emphasises that sustainability in the built environment involves minimising negative environmental impacts while enhancing the quality of life for occupants. In interior design, this includes the selection of eco-friendly materials, energy-efficient systems, and strategies for improving indoor environmental quality.

Pile and Gura (2014) note that interior design has evolved from a primarily aesthetic

discipline to one that incorporates environmental and social considerations. This shift reflects broader societal concerns about climate change, resource depletion, and human health. Sustainable interiors aim to reduce energy consumption, improve air quality, and create spaces that support physical and psychological well-being.

Lifecycle thinking is a key component of sustainable design, emphasising the importance of considering the environmental impact of materials and systems throughout their lifespan (McDonough & Braungart, 2002). This approach encourages designers to prioritise durability, adaptability, and recyclability, thereby reducing waste and extending the lifecycle of interior spaces.

2.2 Integration of Robotics and Sustainability

The integration of architectural robotics into sustainable design practices has gained increasing attention in recent years. Robotic systems offer significant potential for enhancing sustainability by optimising resource use, reducing waste, and enabling adaptive environments (Kolarevic & Parlac, 2015).

One of the primary contributions of robotics to sustainability is in material efficiency. Robotic fabrication allows for precise control over material usage, minimising waste and enabling the use of advanced materials. This precision is particularly valuable in interior design, where space constraints and customisation requirements are often significant.

Energy efficiency is another critical area where robotics can contribute to

sustainability. Smart systems equipped with sensors and automation can optimise lighting, heating, and ventilation based on occupancy and environmental conditions. These systems not only reduce energy consumption but also enhance occupant comfort and well-being.

Adaptive and reconfigurable interiors represent a further dimension of sustainability enabled by robotics. By allowing spaces to be reconfigured as needed, robotic systems reduce the need for new construction and support more efficient use of existing resources. This flexibility is particularly important in urban environments, where space is limited, and demands are constantly changing.

Despite these benefits, the integration of robotics also raises concerns about energy consumption, electronic waste, and the environmental impact of manufacturing robotic systems. Menges and Reichert (2015) caution that the sustainability of robotic systems must be evaluated holistically, considering both their benefits and their lifecycle impacts.

2.3 Ethnography in Design and Technology Studies

Ethnographic approaches have become increasingly important in design research, particularly in the study of technology and user interaction. Ethnography focuses on understanding human behaviour, cultural practices, and social interactions within specific contexts (Pink et al., 2016).

In the context of architectural robotics, ethnography provides insights into how users interact with robotic systems and how these

interactions shape their experiences of space. Pink et al. (2016) argue that ethnographic methods are particularly well-suited to studying smart environments, as they capture the complexities of everyday life and how technologies are embedded in social practices.

Ethnographic research also highlights the importance of context in technology adoption. Factors such as cultural norms, economic conditions, and user preferences influence how robotic systems are used and perceived. This perspective is essential for understanding the broader implications of architectural robotics and for developing design solutions that are inclusive and context-sensitive.

2.4 Human-Technology Interaction in Robotic Environments

Human-Technology Interaction (HTI) is a critical area of research in the context of architectural robotics. Norman (2013) emphasises that the success of technological systems depends on their usability and the extent to which they align with human needs and expectations.

In robotic interiors, HTI involves interactions between users and automated systems, including sensors, interfaces, and control mechanisms. These interactions can enhance convenience and efficiency but also introduce new challenges, such as complexity and loss of control. Designers must carefully consider how users engage with robotic systems to ensure that they are intuitive and accessible.

User acceptance is a key factor in the adoption of robotic technologies. Studies

have shown that users are more likely to embrace technologies that provide clear benefits and are easy to use. Conversely, systems that are perceived as intrusive or difficult to operate may face resistance.

2.5 Actor-Network Theory and Socio-Technical Systems

Actor-Network Theory (ANT) provides a valuable framework for understanding the complex relationships between humans and technologies in architectural robotics. Latour (2005) argues that both human and non-human entities should be considered as actors within a network, each influencing outcomes in different ways.

In the context of robotic interiors, ANT highlights the interconnectedness of designers, users, materials, and technologies. Robotic systems are not merely tools but active participants that shape design processes and user experiences. This perspective challenges traditional distinctions between human agency and technological determinism.

By applying ANT, researchers can better understand how architectural robotics operates as a socio-technical system, where sustainability outcomes are influenced by a network of interacting actors. This approach underscores the importance of considering both technical and social factors in design.

3. Theoretical Framework

The study of architectural robotics and sustainable interiors necessitates an interdisciplinary theoretical framework that integrates perspectives from socio-technical

systems, sustainability science, and human-centred design. This research is grounded in three complementary theoretical approaches: Actor-Network Theory (ANT), Sustainable Design Theory, and Human-Technology Interaction (HTI). Together, these frameworks provide a comprehensive lens for examining the complex relationships between humans, technologies, and environments in contemporary interior design practices.

3.1 Actor-Network Theory (ANT)

Actor-Network Theory (ANT), developed by Latour (2005), offers a foundational perspective for understanding the distributed agency within socio-technical systems. ANT challenges traditional dichotomies between human and non-human actors by treating both as integral components of networks that collectively shape outcomes. In the context of architectural robotics, this means that robotic systems, software algorithms, sensors, materials, designers, and users are all considered “actors” that interact and influence the design and performance of interior environments.

Applying ANT to architectural robotics reveals that robotic systems are not passive tools but active participants in shaping spatial configurations and user experiences. For instance, a robotic shading system that automatically adjusts based on sunlight conditions does not merely execute pre-programmed instructions; it interacts dynamically with environmental inputs and user behaviours, thereby influencing energy consumption and occupant comfort (Kolarevic & Parlac, 2015). This perspective emphasises the relational nature of design,

where outcomes emerge from the interactions among multiple actors rather than from a single controlling entity.

Furthermore, ANT highlights the importance of networks in sustaining technological systems. The effectiveness of architectural robotics depends on the integration of hardware, software, maintenance practices, and user engagement. Disruptions in any part of this network, such as system failures or user resistance, can impact overall performance. Therefore, understanding these networks is crucial for designing resilient and sustainable interior environments.

3.2 Sustainable Design Theory

Sustainable Design Theory provides the environmental and ethical foundation for this study. Rooted in ecological principles, sustainable design seeks to minimise negative environmental impacts while promoting resource efficiency and social well-being (Kibert, 2016). In interior design, sustainability encompasses material selection, energy efficiency, indoor environmental quality, and lifecycle considerations.

McDonough and Braungart's (2002) "cradle-to-cradle" framework is particularly relevant, as it advocates for designing products and systems that can be continuously reused or recycled without generating waste. This approach aligns with the capabilities of architectural robotics, which can facilitate precise material usage, modular construction, and adaptive reuse of interior components. For example, robotic fabrication techniques can produce components with minimal waste, while reconfigurable robotic systems

can extend the lifecycle of interior spaces by enabling flexible use.

Sustainable Design Theory also emphasises the integration of environmental, economic, and social dimensions of sustainability. While architectural robotics can enhance environmental performance through energy optimisation and resource efficiency, it also raises questions about economic accessibility and social equity. The high cost of robotic systems may limit their adoption in certain contexts, potentially exacerbating disparities in access to sustainable design solutions.

Additionally, the environmental impact of manufacturing and maintaining robotic systems must be considered. While these systems can reduce operational energy use, their production involves energy-intensive processes and the use of electronic components that may contribute to environmental degradation (Menges & Reichert, 2015). Therefore, a holistic evaluation of sustainability is necessary, considering both the benefits and trade-offs of integrating robotics into interior design.

3.3 Human-Technology Interaction (HTI)

Human-Technology Interaction (HTI) provides a user-centred perspective on the integration of robotics into interior environments. Norman (2013) emphasises that the success of technological systems depends on their usability, accessibility, and alignment with human needs and expectations. In the context of architectural robotics, HTI focuses on how users interact with automated systems and how these

interactions influence their experiences of space.

Robotic interiors introduce new modes of interaction, such as gesture-based controls, voice commands, and automated responses to environmental conditions. These interactions can enhance convenience and efficiency, but also require users to adapt to unfamiliar technologies. The design of intuitive interfaces and transparent system behaviour is therefore critical for ensuring user acceptance and satisfaction.

HTI also addresses the psychological and emotional dimensions of human-technology relationships. Users may perceive robotic systems as empowering or intrusive, depending on how they are designed and implemented. For example, automated lighting systems that adjust without user input may improve energy efficiency but could also lead to a perceived loss of control. Designers must balance automation with user agency to create environments that are both efficient and empowering.

Moreover, HTI highlights the importance of inclusivity in design. Robotic systems should be accessible to users with diverse abilities, backgrounds, and technological literacy levels. This consideration is particularly important in the context of sustainable design, which aims to promote social equity alongside environmental responsibility.

3.4 Integrative Perspective

The integration of ANT, Sustainable Design Theory, and HTI provides a robust framework for analysing architectural robotics in sustainable interiors. ANT emphasises the networked relationships

among actors, Sustainable Design Theory focuses on environmental and ethical considerations, and HTI highlights user experiences and interactions.

Together, these frameworks enable a holistic understanding of how architectural robotics operates as a socio-technical system that influences sustainability outcomes. They underscore the need for interdisciplinary approaches that consider technical, environmental, and human factors in the design of robotic interiors.

4. Methodology

This study adopts a qualitative research design grounded in ethnographic principles to explore the intersection of architectural robotics and sustainable interior design. Qualitative research is particularly suitable for investigating complex socio-technical phenomena, as it allows for an in-depth understanding of processes, relationships, and meanings (Creswell & Poth, 2018). The ethnographic orientation of the study emphasises the cultural and experiential dimensions of technological adoption, focusing on how architectural robotics is integrated into contemporary design practices.

Given the scope and nature of the research, the study employs a secondary data-based ethnographic approach. This approach involves the analysis of existing data sources, such as academic literature, case studies, and industry reports, to construct an ethnographic understanding of practices and interactions. While traditional ethnography relies on primary fieldwork, secondary data analysis

offers a practical alternative for examining a broad range of contexts and practices.

4.1 Data Sources and Selection Criteria

The study draws on a diverse range of secondary data sources to ensure a comprehensive analysis. These sources include:

- Peer-reviewed journal articles on architectural robotics, sustainable design, and human-technology interaction
- Books and monographs providing theoretical and conceptual frameworks
- Architectural case studies documenting the implementation of robotic systems
- Industry reports and white papers on smart buildings and automation technologies

The selection of data sources is guided by criteria such as relevance, credibility, and recency. Priority is given to peer-reviewed publications and authoritative texts to ensure the reliability of the analysis. Additionally, case studies are selected based on their relevance to the integration of robotics in interior environments and their contribution to sustainability outcomes.

4.2 Data Collection and Organisation

Data collection involves a systematic review of the selected sources, with a focus on identifying information related to the research questions. Relevant data are

extracted and organised into thematic categories, including:

- Material efficiency and resource use
- Energy optimisation and environmental performance
- Spatial adaptability and reconfigurability
- User interaction and experience
- Socio-cultural implications

This process ensures that the data are structured in a way that facilitates analysis and interpretation.

4.3 Data Analysis: Thematic Approach

The study employs thematic analysis as the primary method of data analysis. Thematic analysis involves identifying, analysing, and interpreting patterns within qualitative data (Braun & Clarke, 2006). This method is well-suited to the study's objectives, as it allows for the exploration of recurring themes and relationships across diverse data sources.

The analysis follows a systematic process:

- **Familiarisation with the data** through repeated reading of sources
- **Coding** of relevant data segments based on key concepts and themes
- **Theme development** by grouping related codes into broader categories
- **Interpretation** of themes in relation to the theoretical framework

The use of multiple data sources enhances the validity of the findings by enabling triangulation, where insights from different sources are compared and corroborated.

4.4 Ethnographic Interpretation

Although the study relies on secondary data, it adopts an ethnographic perspective by focusing on practices, interactions, and meanings associated with architectural robotics. This involves interpreting data in terms of how users and designers experience and engage with robotic systems, as well as how these systems are embedded in cultural and organisational contexts (Pink et al., 2016).

Ethnographic interpretation allows the study to capture the complexity of socio-technical systems and to move beyond purely technical analyses. It provides insights into the lived experiences of users and the cultural dynamics of design practices.

4.5 Reliability and Validity

Ensuring the reliability and validity of qualitative research is essential for producing credible findings. This study employs several strategies to enhance rigour:

- **Triangulation:** Using multiple data sources to corroborate findings
- **Theoretical grounding:** Anchoring analysis in established theoretical frameworks
- **Transparent methodology:** Clearly documenting data collection and analysis processes

These strategies contribute to the trustworthiness of the research and support the validity of the conclusions.

4.6 Ethical Considerations

The study adheres to ethical research standards by using publicly available data

and properly citing all sources. As no primary data involving human participants are collected, issues related to informed consent and confidentiality are minimal. However, the study maintains academic integrity by accurately representing the work of other researchers and avoiding plagiarism (Mannan & Farhana, 2026).

4.7 Limitations of the Methodology

While the use of secondary data provides broad coverage, it also presents certain limitations. The absence of primary fieldwork means that the study relies on existing interpretations and may not capture the full depth of user experiences. Additionally, the availability of data may be skewed toward technologically advanced contexts, potentially limiting the generalizability of the findings.

Despite these limitations, the methodology provides a robust foundation for exploring the intersection of architectural robotics and sustainable interiors. It enables the synthesis of diverse perspectives and contributes to a comprehensive understanding of contemporary practices.

5. Findings and Analysis

The analysis of secondary ethnographic data reveals that architectural robotics plays a transformative role in shaping sustainable interior environments. The findings are organised into five interrelated thematic domains: material efficiency and circularity, energy optimisation and environmental responsiveness, spatial adaptability and lifecycle extension, human-technology interaction and experiential dynamics, and

socio-cultural transformations in design practice. These themes collectively demonstrate how architectural robotics functions as a socio-technical system influencing sustainability outcomes across multiple scales.

5.1 Material Efficiency and Circularity

One of the most significant contributions of architectural robotics to sustainable interiors is the enhancement of material efficiency through precision fabrication and reduced waste. Robotic systems, particularly those used in digital fabrication, enable highly accurate cutting, assembly, and material placement, minimising errors and excess (Gramazio et al., 2014). Unlike conventional construction processes, which often involve over-ordering and manual adjustments, robotic fabrication allows for exact material quantities to be used, thereby reducing waste streams.

From a lifecycle perspective, this precision aligns with the principles of the circular economy and cradle-to-grave design (McDonough & Braungart, 2002). Ethnographic accounts of design practices reveal that architects increasingly rely on parametric modelling and robotic fabrication to produce modular components that can be disassembled and reused. This modularity not only reduces construction waste but also supports the adaptability of interior spaces over time.

However, the data also indicate a tension between material efficiency during construction and the environmental impact of producing robotic systems themselves. The

manufacturing of robotic components often involves energy-intensive processes and the use of rare materials, raising concerns about embodied energy and resource extraction (Menges & Reichert, 2015). Thus, while robotics enhances operational efficiency, its overall sustainability must be evaluated within a broader lifecycle framework.

5.2 Energy Optimisation and Environmental Responsiveness

Architectural robotics significantly contributes to energy efficiency through the implementation of responsive environmental systems. Smart interiors equipped with sensors and actuators can dynamically adjust lighting, temperature, and ventilation based on real-time data, optimising energy use and improving occupant comfort (Kolarevic & Parlac, 2015).

Ethnographic observations from case studies indicate that these systems often operate seamlessly in the background, creating environments that respond intuitively to user presence and environmental conditions. For instance, automated shading devices can regulate solar gain, reducing the need for artificial cooling, while adaptive lighting systems adjust brightness and colour temperature to match circadian rhythms.

These capabilities align with sustainable design principles that emphasise energy conservation and indoor environmental quality (Kibert, 2016). However, the reliance on automated systems also introduces new complexities. Users may become dependent on these systems, and system failures can disrupt environmental comfort. Additionally, the energy required to operate and maintain

these systems must be considered in evaluating their overall sustainability.

5.3 Spatial Adaptability and Lifecycle Extension

A key finding of this study is the role of architectural robotics in enabling adaptive and reconfigurable interior spaces. Robotic systems, such as movable partitions, transformable furniture, and kinetic structures, allow spaces to be reconfigured in response to changing needs. This adaptability supports the efficient use of space and reduces the need for new construction, thereby extending the lifecycle of interior environments.

From an ethnographic perspective, users perceive these adaptive environments as flexible and responsive, enabling a range of activities within a single space. For example, a workspace can be transformed into a meeting area or a relaxation zone through the movement of robotic elements. This flexibility is particularly valuable in urban contexts, where space is limited, and multifunctionality is essential.

The concept of adaptability is closely linked to sustainability, as it reduces resource consumption and waste associated with renovation and demolition (Kolarevic & Parlac, 2015). However, the implementation of adaptive systems requires careful design to ensure reliability and ease of use. Complex systems may require specialised maintenance, which can limit their accessibility and long-term viability.

5.4 Human-Technology Interaction and Experiential Dynamics

The integration of robotics into interior environments fundamentally alters the way users interact with space. Human-Technology Interaction (HTI) emerges as a critical factor in determining the success and sustainability of robotic interiors. According to Norman (2013), user experience is shaped by the usability and intuitiveness of technological systems.

Ethnographic data reveal that users often experience a mix of empowerment and uncertainty when interacting with robotic systems. On one hand, automation enhances convenience by reducing the need for manual control. On the other hand, users may feel a loss of agency when systems operate autonomously without clear feedback or control mechanisms.

The design of user interfaces plays a crucial role in mediating these experiences. Systems that provide transparent feedback and allow for user customisation are more likely to be accepted and effectively utilised. Conversely, opaque or overly complex systems may lead to frustration and resistance.

Furthermore, HTI in robotic interiors extends beyond functional interactions to include emotional and psychological dimensions. Users may develop trust or mistrust in automated systems based on their reliability and responsiveness. These affective responses influence how users engage with technology and, ultimately, how sustainable behaviours are enacted within these environments.

5.5 Socio-Cultural Transformations in Design Practice

The adoption of architectural robotics is not only a technological shift but also a cultural transformation that reshapes design practices and professional roles. Actor-Network Theory (Latour, 2005) provides a useful lens for understanding these changes, as it emphasises the interconnectedness of human and non-human actors.

Ethnographic evidence suggests that architects and interior designers are increasingly collaborating with engineers, programmers, and data scientists to develop robotic systems. This interdisciplinary approach reflects the complexity of contemporary design challenges and the need for integrated solutions.

Moreover, the presence of robotic systems in interior environments influences user behaviours and cultural norms. For example, users may adapt their routines to align with automated systems, such as scheduling activities based on environmental conditions. These changes highlight the reciprocal relationship between technology and culture.

However, the integration of robotics also raises concerns about accessibility and equity. High costs and technical complexity may limit the adoption of these systems to affluent contexts, potentially exacerbating social inequalities. Addressing these challenges requires a commitment to inclusive design and the development of scalable solutions.

6. Discussion

The findings of this study underscore the transformative potential of architectural robotics in advancing sustainable interior design. However, they also reveal the complexity of integrating technological innovation with environmental, social, and cultural considerations. This discussion synthesises the findings through the lens of the theoretical framework, highlighting key implications and critical tensions.

6.1 Architectural Robotics as a Socio-Technical System

From the perspective of Actor-Network Theory (Latour, 2005), architectural robotics can be understood as a socio-technical system in which humans and technologies are co-constitutive actors. The findings demonstrate that robotic systems actively shape design processes, user interactions, and sustainability outcomes, rather than merely serving as tools.

This perspective challenges traditional notions of design authorship, as the agency is distributed across a network of actors, including algorithms, sensors, and users. Designers must therefore navigate a complex landscape in which control is shared and outcomes are emergent. This shift has significant implications for design education and practice, requiring new skills and collaborative approaches.

6.2 Sustainability Beyond Efficiency

While architectural robotics offers clear benefits in terms of material efficiency and energy optimisation, the findings highlight the need for a broader understanding of

sustainability. Sustainable Design Theory emphasises the importance of considering environmental, social, and economic dimensions (Kibert, 2016).

The lifecycle impacts of robotic systems present a critical challenge. Although these systems can reduce operational energy use, their production and disposal may contribute to environmental degradation. This paradox underscores the importance of adopting a holistic approach to sustainability that considers both short-term benefits and long-term impacts (Menges & Reichert, 2015).

Furthermore, the social dimension of sustainability is evident in issues of accessibility and equity. The high cost of robotic systems may limit their adoption, raising questions about who benefits from these technologies. Addressing these disparities requires policies and design strategies that promote inclusivity and affordability.

6.3 Human-Centred Design in Robotic Environments

The findings emphasise the importance of Human-Technology Interaction (HTI) in shaping user experiences and sustainability outcomes. As Norman (2013) argues, the success of technological systems depends on their alignment with human needs and expectations.

In robotic interiors, the balance between automation and user control is particularly critical. While automation can enhance efficiency, excessive reliance on automated systems may undermine user agency and engagement. Designers must therefore create systems that are both intelligent and user-

centred, allowing for meaningful interaction and control.

The ethnographic perspective highlights the importance of understanding user behaviours and cultural contexts in the design of robotic systems. Technologies that are culturally sensitive and adaptable to different contexts are more likely to be accepted and effectively utilised.

6.4 Adaptability and Resilience

The ability of architectural robotics to enable adaptive and reconfigurable interiors represents a significant advancement in sustainable design. By supporting flexible use of space, these systems reduce the need for new construction and extend the lifecycle of interior environments.

This adaptability also contributes to resilience, allowing spaces to respond to changing conditions and user needs. In the context of rapid urbanisation and environmental uncertainty, such flexibility is increasingly important. However, the complexity of adaptive systems requires careful design to ensure reliability and maintainability.

6.5 Cultural and Ethical Implications

The integration of robotics into interior environments raises important cultural and ethical questions. The findings suggest that robotic systems influence not only physical spaces but also social practices and cultural norms. Users adapt their behaviours to align with automated systems, leading to new forms of interaction and experience.

Ethical considerations include issues of privacy, data security, and autonomy. Smart systems often rely on data collection to function effectively, raising concerns about how this data is used and protected. Additionally, the increasing autonomy of robotic systems raises questions about accountability and control.

Addressing these ethical challenges requires a multidisciplinary approach that integrates technical expertise with ethical and social considerations. Designers, engineers, and policymakers must work together to develop frameworks that ensure the responsible use of technology.

6.6 Implications for Future Research and Practice

The findings of this study highlight several areas for future research and practice. First, there is a need for primary ethnographic studies that explore user experiences in real-world robotic environments. Such studies can provide deeper insights into the social and cultural dimensions of technological adoption.

Second, interdisciplinary collaboration is essential for advancing the integration of architectural robotics and sustainable design. Bringing together expertise from architecture, engineering, social sciences, and environmental studies can lead to more holistic and effective solutions.

Finally, there is a need for policy frameworks that support the equitable and sustainable deployment of robotic technologies. These frameworks should address issues of accessibility, affordability, and environmental impact, ensuring that the

benefits of technological innovation are widely distributed.

7. Conclusion

This study has explored the intersection of architectural robotics and sustainable interior design through an ethnographic analysis of contemporary practices, employing a qualitative methodology grounded in secondary data. The findings demonstrate that architectural robotics significantly contributes to sustainability by enhancing material efficiency, optimising energy performance, and enabling adaptable and reconfigurable interior environments. These capabilities align with broader sustainability goals, particularly in reducing resource consumption and extending the lifecycle of built spaces.

At a theoretical level, the integration of Actor-Network Theory, Sustainable Design Theory, and Human-Technology Interaction provides a comprehensive understanding of how robotic systems operate within complex socio-technical networks. Architectural robotics is not merely a technological tool but an active participant in shaping spatial practices, user experiences, and environmental outcomes. This perspective highlights the distributed agency among designers, users, and technological systems, emphasising the need for interdisciplinary approaches in design practice.

However, the study also identifies several critical challenges. While robotic systems improve operational efficiency, their production and maintenance raise concerns about embodied energy, electronic waste, and

long-term environmental impact. Additionally, issues of accessibility and affordability may limit the widespread adoption of these technologies, potentially reinforcing social inequalities. The findings further reveal that user experience and acceptance are crucial factors, as overly automated or complex systems can undermine user agency and engagement.

From a practical standpoint, the study underscores the importance of human-centred design in the development of robotic interiors. Designers must balance automation with user control, ensuring that technological systems are intuitive, inclusive, and responsive to diverse needs. Moreover, ethical considerations related to data privacy, system autonomy, and cultural adaptation must be addressed to ensure responsible implementation.

In conclusion, architectural robotics holds significant potential to redefine sustainable interior design by enabling dynamic, efficient, and user-responsive environments. However, realising this potential requires a holistic approach that integrates technological innovation with environmental responsibility, social equity, and cultural sensitivity. Future research should focus on primary ethnographic investigations and interdisciplinary collaboration to further explore the long-term implications and practical applications of robotic systems in interior environments.

References

Bock, T., & Linner, T. (2015). *Robot-oriented design: Design and management*

tools for the deployment of automation and robotics in construction. Cambridge University Press.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). Sage Publications.

Gramazio, F., Kohler, M., & Willmann, J. (2014). *The robotic touch: How robots change architecture*. Park Books.

Kibert, C. J. (2016). *Sustainable construction: Green building design and delivery* (4th ed.). Wiley.

Kolarevic, B., & Parlac, V. (2015). *Building dynamics: Exploring architecture of change*. Routledge.

Latour, B. (2005). *Reassembling the social: An introduction to actor-network theory*. Oxford University Press.

Mannan, K.A., & Farhana, K.M. (2026). *The Principles of Qur'anic Research Methodology: Deriving the Process of Knowledge from Revelation*. KMF Publishers. Open Access (CC BY 4.0). DOI: <https://doi.org/10.64907/xkmf.book.pqrm.26.02.12>

- McDonough, W., & Braungart, M. (2002). *Cradle to cradle: Remaking the way we make things*. North Point Press.
- Menges, A., & Reichert, S. (2015). Material capacity: Embedded responsiveness. *Architectural Design*, 85(5), 52–59. <https://doi.org/10.1002/ad.1953>
- Norman, D. A. (2013). *The design of everyday things* (Revised and expanded ed.). Basic Books.
- Pink, S., Mackley, K. L., Morosanu, R., Mitchell, V., Bhamra, T., Arnold, M., & Harris, J. (2016). *Making homes: Ethnography and design*. Bloomsbury Academic.