Human-Centered Construction Organizations: Analyzing the Integration of Lean Construction Principles with Human-Centric Approaches

Ali Bidhendi
Auckland University of Technology, ali.bidhendi@autuni.ac.nz

Mani Poshdar
Auckland University of Technology, mani.poshdar@aut.ac.nz

Mostafa Jelodar
Massey University, m.b.jelodar@massey.ac.nz

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Human-Centered Construction Organizations: Analyzing the Integration of Lean Construction Principles with Human-Centric Principles

Ali Bidhendi, ali.bidhendi@autuni.ac.nz
Department of Built Environment Engineering, School of Future Environments, Auckland University of Technology (AUT), New Zealand

Mani Poshdar, mani.poshdar@aut.ac.nz
Department of Built Environment Engineering, School of Future Environments, Auckland University of Technology (AUT), New Zealand

Mostafa Babaeian Jelodar, m.b.jelodar@massey.ac.nz
School of Built Environment, College of Science, Massey University, New Zealand

Abstract
The construction industry is undergoing a significant transformation, driven by the advancements of digital transformation and the emerging paradigm of Industry 5.0. While these developments bring opportunities for increased efficiency and productivity, they also present challenges in integrating human-centric approaches within the digital transformation initiatives. While both lean construction principles and human-centric approaches aim to improve organizational performance, their integration and mutual relationships remain understudied. This paper examines the intersection of human-centric approaches with lean construction principles in construction organizations, focusing on the concept of Human-Centered Construction Organizations (HCCOs) advancing sustainability objectives aligning with the United Nations Sustainable Development Goals (SDGs) and the objectives of relevant CIB commissions. This paper implements a multi-step methodology to identify and analyze the relationship between lean construction principles and human-centric approaches in construction organizations. Through systematic literature review and advanced network analysis techniques; the study examines how lean construction principles support and enhance human-centric approaches. The findings reveal significant interconnections between specific lean construction principles and human-centric elements, with productivity improvement, safety enhancement, and environmental consideration emerging as central nodes in the network. The analysis identified 35 lean construction principles and 31 human-centric approaches, demonstrating dense interconnections with a graph density of 27. Key human-centric approaches, including individual cognitive abilities, problem-solving capabilities, and effective communication channels, were found to be frequently integrated within lean construction principles. This research contributes to the body of knowledge by providing a quantitative understanding of how lean construction principles can support human-centric transformation in construction organizations, offering practical insights for industry practitioners and researchers.

Keywords
Human-centric approach, Lean Construction, Industry 5.0.

1 Introduction

The construction industry is undergoing a significant transformation as it moves from the technology-centric focus of Industry 4.0 to a more human-centric approach of Industry 5.0. While Industry 4.0 advanced automation and digitalization, resulting in increased efficiency and productivity (Bradu et al., 2022; Qureshi, 2024), often overlooked the integration of human factors within organizations (Herrmann and Pfeiffer, 2023). As Industry 4.0 technologies continue to evolve, there has been a notable shift from the original principles of human-centricity towards a stronger focus on digital and AI-driven efficiency (Zizic et al., 2022). This shift raises critical questions regarding the role of human intelligence and the need to reorient towards human-centric methodologies within construction organizations (Leng et al., 2022; Herrmann and Pfeiffer, 2023). The construction sector, therefore, faces unprecedented challenges in aligning technological advancements with the human dimensions of the industry, necessitating a strategic rethinking of organizational structures and processes (Veling, 2014). This shift highlights the need for a more balanced approach that incorporates human elements alongside technological advancements, addressing a critical gap in construction management practices (Leng et al., 2022).

Industry 5.0 presents a significant shift, moving from the dominance of technology to a more collaborative approach that prioritizes human creativity and innovation with advanced technological capabilities. According to Schwab (2016) this approach underscores the importance of human-centered organizations, where human intelligence and technology work together to foster innovation and productivity. As Hirsch-Kreinsen (2016) notes, Industry 5.0 emphasizes attributes such as creativity, emotional intelligence, and cognitive flexibility, all essential for driving sustainable and inclusive growth in the digital era.

Reports from major corporations indicate that human-centered organizations benefit from significant performance improvements, including a 1.5-fold increase in revenue growth (Deloitte, 2021) and a 25% increase in profitability (McKinsey & Company, 2023). Furthermore, these organizations report a 20% higher employee retention rate, a crucial metric given the costs associated with turnover (SHRM, 2022). Despite these promising results in other industries, the integration of human-centric principles with lean construction practices in the construction industry remains underexplored.

Lean construction derived from manufacturing principles, focuses on process optimization through waste reduction, value creation and continuous improvement (Koskela, 1992; Abdelhamid, El-Gafy and Salem, 2008). While this approach has proven effective for operational efficiency, the increasing complexity of construction projects and emphasis on human factors in Industry 5.0 necessitate a more comprehensive framework. On the other hand, human-centric approaches emphasize employee well-being, cognitive flexibility, and inclusive work environments (Townsend, 2024). While both methodologies aim to enhance organizational performance, the potential synergies between them and how they can be integrated have not been systematically studied.

To address this research gap, this study employs a multi-step methodology combining systematic literature review with social network analysis (SNA) techniques, as successfully used in previous construction management research (Sheikhkhoshkar et al., 2023). The objectives of the study are to identify and quantify the relationship between lean construction principles and human-centric approaches through systematic literature review and network analysis, thereby establishing a foundation for understanding their integration patterns in construction organizations.

This research is significant as it offers a pathway to bridge the gap between lean construction principles and human-centric strategies, delivering actionable insights for construction firms aiming to evolve in an increasingly complex industry landscape. With the World Economic Forum predicting that over

half of all employees will require reskilling by 2025, understanding this integration is critical for the sustainable future of construction.

The rest of the paper is structured as follows: Section 2 provides a brief research background. Section 3 outlines the research methodology, detailing the systematic literature review and social network analysis approaches. Section 4 presents the results of the network analysis, identifying key relationships and patterns. Finally, Section 5 concludes and makes recommendations for future research directions.

2 Literature Review

2.1 Lean Construction

Lean Construction, introduced by Koskela (1992), redefined traditional views of construction by presenting it as a series of value-adding activities rather than just the transformation of materials into structures. This approach focuses on identifying inefficiencies within these processes and implementing strategic solutions for improvement (Gao *et al.*, 2023).

Rooted in the principles of lean manufacturing developed through the Toyota Production System, Lean Construction emphasizes waste reduction, enhanced efficiency, and value delivery to clients. Pioneers in the field, Glenn Ballard and Lauri Koskela, have extensively studied this philosophy, advocating its application beyond standardized or large-scale projects to more dynamic and innovative ones that drive value (Ballard and Koskela, 1998). Ballard and Howell further argue that Lean Construction is not synonymous with cost-cutting or minimizing quality; rather, it prioritizes value creation for customers by eliminating unnecessary elements (Ballard and Howell, 2003). The four foundational principles of Lean Construction include: Waste Minimization, which targets the reduction of non-value-adding activities and materials; Value Maximization, focused on optimizing client value through efficient practices; Continuous Improvement, involving the regular assessment and refinement of processes for better performance; and Respect for People, emphasizing the importance of the welfare and growth of everyone involved in construction (Aziz and Zainon, 2023; Bidhendi *et al.*, 2024; Bigwanto *et al.*, 2024).

2.2 Human-Centric Approaches in Organizational Evolution

The evolution of organizations over the past three centuries has been marked by three industrial revolutions, with many experts now suggesting that we are in the midst of a fourth. The time gaps between these major shifts have shortened, with the first three occurring approximately a century apart, and the fourth following just four decades after the third. It is conceivable that the fifth stage could emerge within a similar timeframe (Caradonna, 2022). Currently, two main perspectives on Industry 5.0 are gaining attraction: one focusing on "Human-centric transformation," aiming to integrate human and robotic collaboration seamlessly, and the other emphasizing the bio-economy (Jeyaraman, Nallakumarasamy and Jeyaraman, 2022). Regardless of which path Industry 5.0 takes, its influence on organizations is expected to be profound, as technological progress aims to replicate human abilities more closely (Bhatia *et al.*, 2023).

In the digital age, construction organizations increasingly value a human-centric approach, understanding that prioritizing the needs of employees, clients, and stakeholders is essential for success in this rapidly changing field. Construction projects bring together various stakeholders such as architects, engineers, contractors, subcontractors, suppliers, and clients (Paolillo, Olson and Straub, 2016). Implementing a human-centric approach helps organizations manage these stakeholders effectively, leading to project success. Tailoring processes and designs to meet the distinct needs,

preferences, and challenges of each stakeholder can foster collaboration, improve efficiency, and achieve better project outcomes. Additionally, prioritizing human-centricity enhances worker well-being, safety, and job satisfaction, acknowledging the demanding and sometimes hazardous nature of construction work. This approach ensures measures are in place to promote health and safety and cultivates a positive work environment that supports employee growth and development (Cao and Chang, 2014). Given the opportunities and challenges in the current construction sector, strategies for embedding human-centric practices are crucial. Fostering such a culture and utilizing technology to reinforce these practices can help construction firms meet stakeholder needs effectively, enhancing collaboration and productivity (Townsend, 2024).

3 Research Methodology

This study uses a structured, multi-phase approach to explore the connections between lean construction principles and human-centric approaches. Following a post-positivist philosophy, the methodology combines qualitative interpretation with quantitative analysis. Building on similar quantitative analysis studies in construction research (Sheikhkhoshkar *et al.*, 2023) the methodology consists of three steps: (1) conducting a systematic literature review to identify key principles, (2) performing content analysis to examine relationships, and (3) applying social network analysis to measure the interactions between principles. Figure 1 provides a visual summary of the research design.

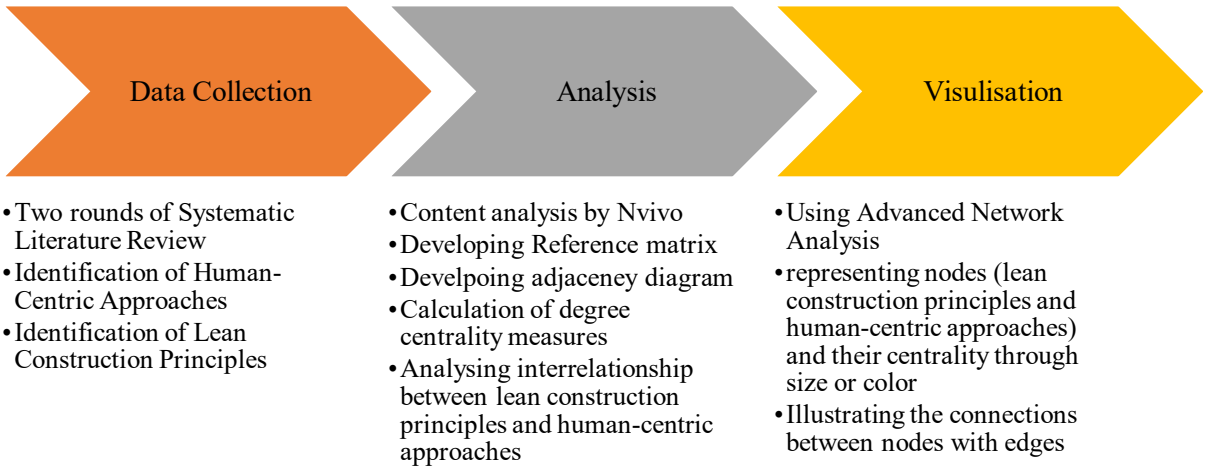

Figure 1. The process of research design

3.1 Systematic Literature Review

The systematic literature review began with searching the Scopus database, focusing on publications until October 2024. The search strategy combined keywords related to lean construction principles and human-centric approaches using Boolean operators "AND" and "OR". Key search terms included variations of "lean construction," "human-centric," "human-centered organization," and "Industry 5.0." Table 1 illustrates the search query.

Table 1. Search query

Parameter	Search term
Scopus	("lean construction" OR "lean principle" OR "lean method" OR "lean approach" OR "lean practice" OR "lean management" OR "lean thinking" OR "Last Planner System" OR "Takt Planning") AND ("human-cent" OR "human cent" OR "human-focus" OR "human focus" OR "human-orient" OR "human orient" OR "people-cent" OR "human factor" OR "human resource" OR "human capital" OR "human aspect" OR "human dimension" OR "industry 5.0" OR "worker wellbeing" OR "employee wellbeing" OR "human value") AND (construction OR "construction industry" OR "construction sector" OR "construction project" OR "construction organization" OR "construction management" OR "construction company" OR "construction firm")

The selection phase involved specific inclusion criteria contained in Articles published in English, peer-reviewed journals and conference proceedings, Research focused on applications within the construction industry, and Publications addressing lean principles or human-centered approaches

3.2 Social Network Analysis

To analyze the relationships between lean principles and human-centric elements, this study employed social network analysis (SNA). The analysis began by creating a reference matrix P where Rows represent identified lean principles, Columns represent human-centric elements, and Cell values indicate relationships between lean construction principles and human-centric approaches (1 for presence, 0 for absence)

The weighted adjacency matrix was computed using the equation:

$$A_{1\times1} = \mathrm{P}_{\mathrm{l}\times\mathrm{m}} \times \mathrm{P}^{\mathrm{T}}_{\mathrm{l}\times\mathrm{m}} \text{for i} \neq \text{j} \qquad (1)$$

Where:

$A_{1\times1}$ = weighted adjacency matrix, $P_{1\times\mathrm{m}}$ = reference matrix, $\mathrm{P}^{\mathrm{T}}_{\mathrm{l}\times\mathrm{m}}$ = transpose of reference matrix, l = number of identified principles, and m = number of relationships

To evaluate the significance of relationships, degree centrality (DC) was calculated for each principle using:

$$DC\_i = \sum\_(\mathrm{j};\ \mathrm{j} \neq \mathrm{i})\ \mathrm{P}\_(\mathrm{i},\mathrm{j}) \qquad (2)$$

Where DC_i represents the degree centrality for principle i, and P_(i,j) represents the value in row i and column j of the adjacency matrix.

The DC values were then normalized using:

$$D\bar{C}\_i = (\mathrm{DC\_i})/(\max\{\mathrm{DC\_k}\}) \qquad (3)$$

This normalization allows for meaningful comparison of centrality across different principles on a scale from 0 to 1. This structured analysis approach enables quantitative assessment of how lean

construction principles support and relate to human-centric elements in construction organizations, providing a foundation for understanding their integration patterns.

4 Findings and Discussion

A systematic search and screening process resulted in the identification of 37 relevant sources, including journals, conference proceedings, and reports, which were used as the basis for the analysis. From this thorough review, 35 lean construction principles were highlighted, enabling the extraction of 31 human-centric approaches. These findings will be discussed in detail in the following sections.

4.1 Systematic Literature Review

This study started with the execution of a systematic literature review (SLR). It concentrated on analyzing different lean construction principles and explored human-centric approaches, specifically related to the construction industry. This SLR followed the PRISMA guidelines, as shown in Figure 2, to maintain a well-structured and transparent methodology. This detailed approach produced an extensive list of lean construction principles and human-centric approaches, which were then refined through content analysis using NVivo software.

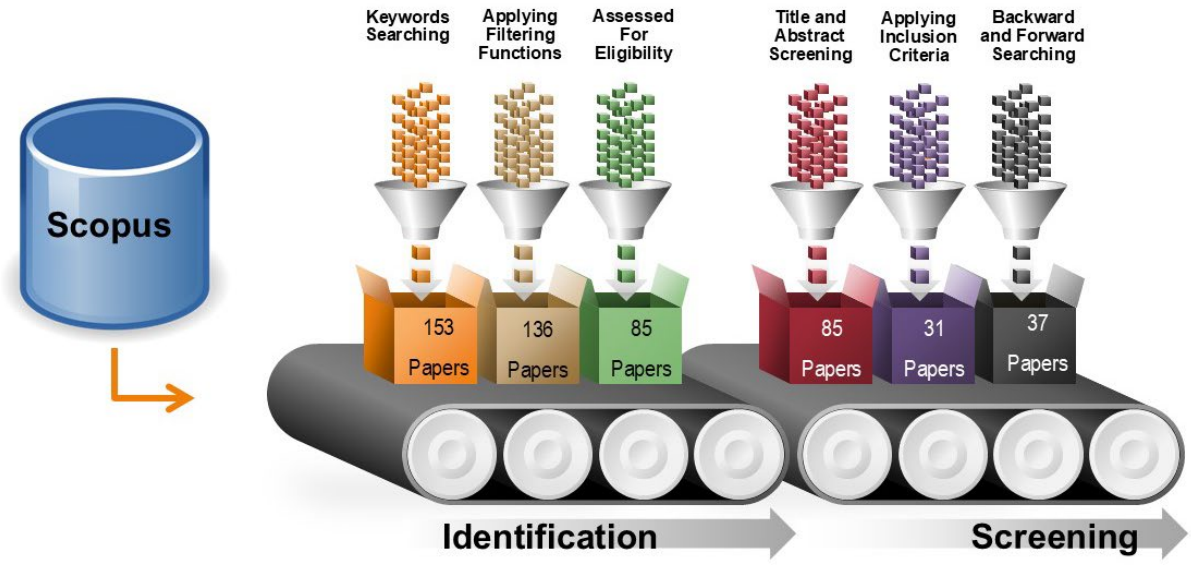

Figure 2. Review Process

4.2 Content Analysis

Following the screening stage, content analysis was conducted on 37 selected papers. Using NVivo software, the finalized papers were systematically examined and coded to identify key lean construction principles and human-centric approaches. Themes were prioritized based on their frequency within the data, grouped accordingly, and presented as nodes representing major themes.

A thorough review of the papers yielded 41 lean construction principles and 48 human-centric approaches. To enhance clarity, similar concepts were consolidated, and irrelevant or duplicated items were removed, resulting in a refined list of 35 lean construction principles and 31 human-centric approaches detailed in Table 2 and Table 3.

Table 2. Identification of lean construction principles

ID	Lean construction principles	ID	Lean construction principles	ID	Lean construction principles
LCP1	Customer requirements fulfillment	LCP13	Work standardization	LCP26	Visual management implementation
LCP2	Value maximization for stakeholders	LCP14	Flow reliability enhancement	LCP27	Information flow improvement
LCP3	Output value enhancement	LCP15	Constraint analysis efficiency	LCP28	Performance transparency
LCP4	Value stream mapping implementation	LCP16	Schedule constructability assurance	LCP29	Progress monitoring clarity
LCP5	Value-adding activities prioritization	LCP17	Performance maximization	LCP30	Project duration optimization
LCP6	Customer-driven process design	LCP19	Total quality control	LCP31	Cost efficiency achievement
LCP7	Systematic waste identification and elimination	LCP20	Process benchmarking	LCP32	Environmental consideration
LCP8	Process simplification	LCP21	Continuous learning implementation	LCP33	Safety enhancement
LCP9	Cycle time optimization	LCP22	Cross-functional team organization	LCP34	Productivity improvement
LCP10	Resource utilization improvement	LCP23	Integrated delivery approaches	LCP35	Quality assurance
LCP11	Material waste minimization	LCP24	Collaborative planning processes		
LCP12	Continuous workflow maintenance	LCP25	Communication enhancement		

Table 3. Identification of human-centric approaches

ID	Lean construction principles	ID	Lean construction principles	ID	Lean construction principles
HCA1	Individual cognitive abilities and emotional intelligence	HCA12	Team integration and coordination	HCA23	System thinking approach
HCA2	Professional competencies and skills development	HCA13	Cross-functional collaboration	HCA24	Ergonomic workspace design
HCA3	Creativity and critical thinking capabilities	HCA14	Effective communication channels	HCA25	User-centered process design
HCA4	Continuous learning and adaptability	HCA15	Knowledge sharing practices	HCA26	Task allocation optimization
HCA5	Problem-solving abilities	HCA16	Cultural awareness and diversity	HCA27	Resource utilization efficiency
HCA6	Decision-making capabilities	HCA17	Empowering leadership approaches	HCA28	Environmental considerations
HCA7	Physical and mental health considerations	HCA18	Performance enhancement systems	HCA29	Social responsibility
HCA8	Safety and security	HCA19	Change management capabilities	HCA30	Stakeholder engagement
HCA9	Privacy and human rights	HCA20	Cultural transformation leadership	HCA31	Innovation promotion
HCA10	Worker satisfaction and motivation	HCA21	Human-machine interaction optimization		
HCA11	Control of overtime and workload	HCA22	Technology adoption support		

Furthermore, Figure 3 shows the mapping of studied lean construction principles and identified human-centric approaches. Dark blue cells indicate that the lean construction principles have attempted to meet human-centric approaches.

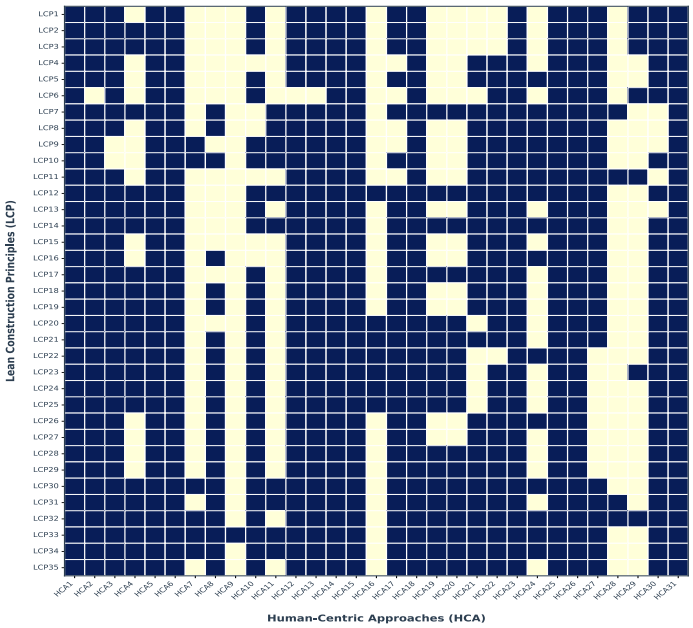

Figure 3. Mapping of studied lean construction principles and identified human-centric approaches

4.3 Quantitative Analysis

Following the detailed analysis and identification of lean construction principles, a reference matrix P was constructed, encompassing the identified lean construction principles and human-centric approaches, resulting in a 35 by 31 matrix.

An adjacency matrix was then generated from the reference matrix using Equation 1. The values within this matrix represent the weight of connections between nodes, with cells color-coded to reflect the strength of these connections, as depicted in Figure 4. White cells between pairs of lean construction principles indicate no co-occurrence in the analyzed scheduling methods, whereas dark blue cells suggest significant co-occurrence, highlighting strong connections, such as those between LCP33 (Safety enhancement) and LCP34 (Productivity improvement).

Figure 5 visualizes the network formed by the adjacency matrix, revealing multiple links among lean construction principles. This demonstrates a dense network, with a graph density of 27, indicating numerous interconnections. The degree of centrality (DC) was computed and normalized to evaluate the level of interconnectivity between lean principles within integrated scheduling methods. The normalized DC results are shown in Table 4.

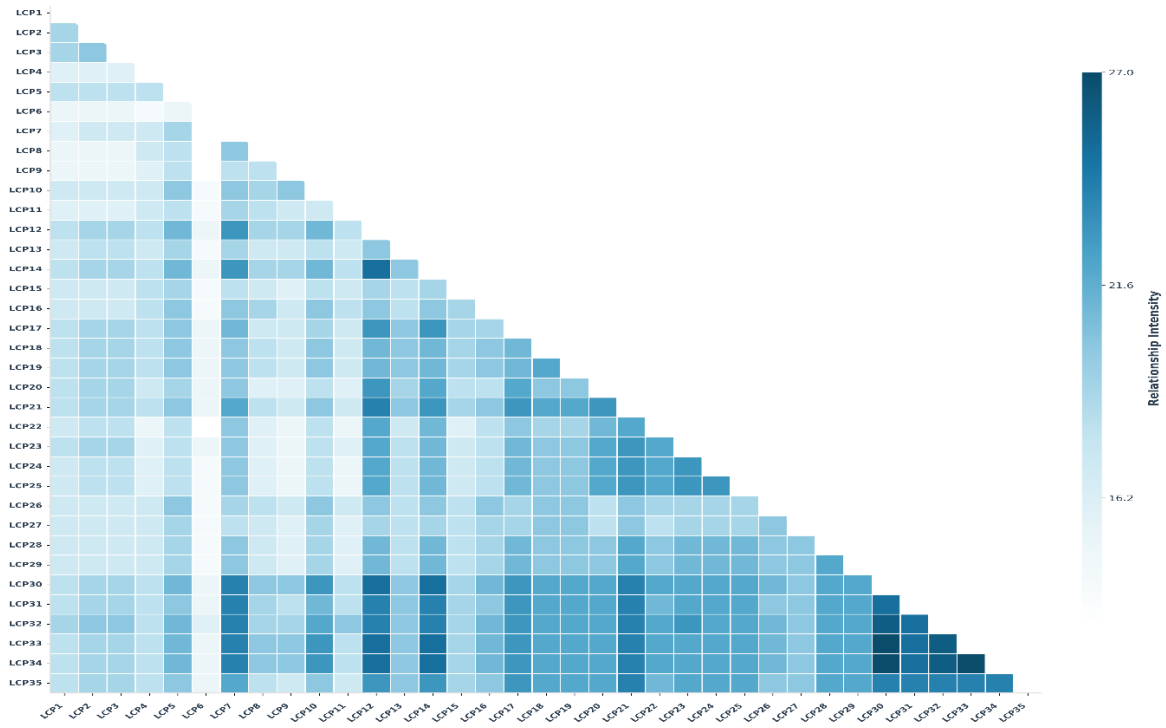

Figure 4. Adjacency matrix of lean construction principles

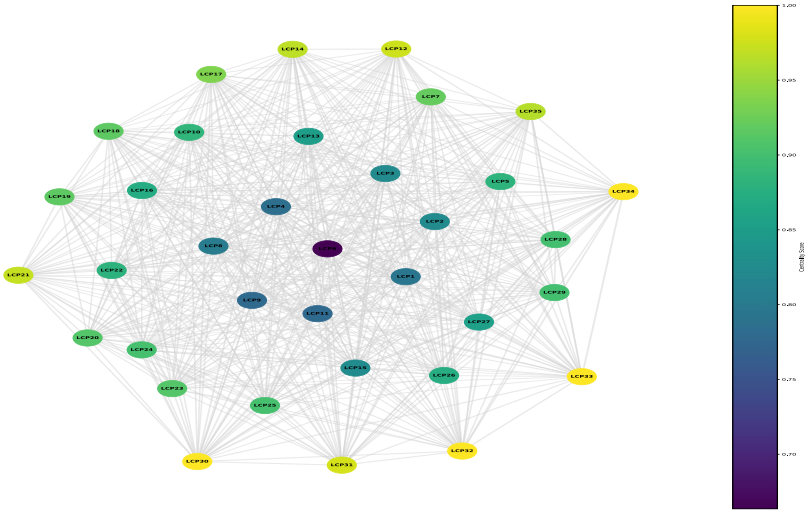

Figure 5. Lean construction principles network

Table 4. Normalized DC

ID (Lean construction principles)	Normalized DC	ID (Lean construction principles)	Normalized DC	ID (Lean construction principles)	Normalized DC
LCP34 (Productivity improvement)	1.000	LCP18 (Zero defect pursuit)	0.916	LCP27 (Information flow improvement)	0.854
LCP33 (Safety enhancement)	1.000	LCP20 (Process benchmarking)	0.909	LCP13 (Work standardization)	0.850
LCP32 (Environmental consideration)	1.000	LCP23 (Integrated delivery approaches)	0.909	LCP15 (Constraint analysis efficiency)	0.824
LCP30 (Project duration optimization)	1.000	LCP25 (Communication enhancement)	0.901	LCP2 (Value maximization for stakeholders)	0.823
LCP31 (Cost efficiency achievement)	0.978	LCP24 (Collaborative planning processes)	0.901	LCP3 (Output value enhancement)	0.823
LCP12 (Continuous workflow maintenance)	0.974	LCP29 (Progress monitoring clarity)	0.900	LCP8 (Process simplification)	0.804
LCP21 (Continuous learning implementation)	0.970	LCP28 (Performance transparency)	0.900	LCP1 (Customer requirements fulfillment)	0.796
LCP14 (Flow reliability enhancement)	0.966	LCP10 (Resource utilization improvement)	0.884	LCP4 (Value stream mapping implementation)	0.785
LCP35 (Quality assurance)	0.962	LCP5 (Value-adding activities prioritization)	0.881	LCP9 (Cycle time optimization)	0.778
LCP17 (Performance maximization)	0.935	LCP22 (Cross-functional team organization)	0.880	LCP11 (Material waste minimization)	0.777
LCP7 (Systematic waste identification and elimination)	0.920	LCP26 (Visual management implementation)	0.873	LCP6 (Customer-driven process design)	0.664
LCP19 (Total quality control)	0.916	LCP16 (Schedule constructability assurance)	0.870		

Recognizing these human-centric approaches and their foundational concepts can help organizational leaders enhance the effectiveness of lean construction. The analysis revealed that individual cognitive abilities and emotional intelligence, problem-solving abilities, decision-making capabilities, effective communication channels, knowledge sharing practices, user-centered process design, task allocation optimization, and innovation promotion were the most frequently applied human-centric approaches within lean construction principles. While various lean construction principles, including productivity enhancement, safety measures, environmental considerations, and project duration optimization, have leveraged these human-centric strategies, a few have seen limited focus.

5 Conclusions and Further Research

This study has provided a comprehensive analysis of the integration between lean construction principles and human-centric approaches through a systematic literature review and social network analysis. The research has revealed several significant findings that contribute to both theoretical understanding and practical implementation of human-centric transformation in construction organizations. The network analysis demonstrated strong interconnections between lean construction principles and human-centric approaches, with certain principles showing particularly high centrality

values. Productivity improvement, safety enhancement, and environmental consideration emerged as the most central principles (normalized DC = 1.000), indicating their crucial role in supporting human-centric transformation. These findings suggest that organizations should prioritize these areas when implementing integrated approaches. The study identified key human-centric approaches that are frequently incorporated within lean construction principles, including individual cognitive abilities, problem-solving capabilities, and effective communication channels. This integration suggests a natural alignment between lean construction principles and human-centric approaches, offering opportunities for organizations to enhance both operational efficiency and human factors simultaneously. The research also revealed areas where integration could be strengthened. Customer-driven process design showed the lowest centrality value (0.664), indicating an opportunity for better integration with human-centric approaches. This suggests that organizations should pay particular attention to incorporating human factors in their process design activities. Future studies should validate these theoretical relationships through case studies and empirical research in construction organizations. Studies should develop specific metrics to measure the success of human-centric lean implementation in construction projects. Further research could explore how different types of construction projects might require different approaches to human-centric lean implementation. This research provides a foundation for understanding the relationship between lean principles and human-centric approaches in construction organizations. The findings offer valuable insights for practitioners seeking to implement more balanced and effective organizational transformation strategies in the construction industry.

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