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Examining the impact of human factors on lean construction scheduling through network and feedback analysis

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Abstract

Purpose – This research aims to examine the complex interrelationships of human-related barriers that significantly affect lean construction scheduling in the New Zealand construction industry and rank them to support targeted intervention.

Design/methodology/approach – A qualitative design was used, combining a systematic literature review (SLR) of 77 peer-reviewed studies with semi-structured interviews involving five industry experts. The analysis applied thematic coding and network-based measures, including frequency, degree of centrality and eigenvector centrality, to identify and rank influential factors.

Findings – The SLR produced 615 human-related factors, which were consolidated into 54 unique categories. Analysis revealed six factors as most critical: lower motivation and engagement, inadequate collaboration among stakeholders, weak top management support, cultural resistance to change, a conservative, negative attitude and limited conceptual knowledge. These factors were frequently cited in the literature and held a strong systemic influence in network analysis. Interviews confirmed their practical relevance while also pointing to additional issues such as psychological safety and leadership style. Addressing these human-centred barriers is therefore essential to achieving the intended benefits of lean scheduling.

Research limitations/implications – Generalising findings from the SLR may overlook local details or project-specific outcomes. The primary data were limited to a small expert sample, restricting the breadth of perspectives. In addition, external influences such as financial constraints, supply chain issues and regulatory factors were excluded, which may also affect lean scheduling outcomes.

Practical implications – The results provide clear priorities for practice, including stronger leadership commitment, structured training, enhanced collaboration and strategies to overcome cultural barriers. Implementing these interventions can strengthen lean adoption and improve project outcomes in New Zealand.

Social implications – This research carries important social implications by emphasising the human dimension of productivity in the construction sector. It highlights how motivation, collaboration, leadership and learning culture directly influence not only project outcomes but also workplace well-being and professional development. By addressing these human factors, the study encourages more inclusive, communicative and supportive work environments that value participation and continuous learning. Ultimately, improving these social dynamics can strengthen teamwork, job satisfaction and long-term workforce sustainability within the construction industry.

Originality/value – Previous studies have examined individual factors affecting lean construction scheduling but often in isolation. This research highlights how human-related barriers interact and how their interrelationships influence outcomes. Using network-based methods, including causal loop diagrams and centrality measures, the study identifies not only the most frequent factors but also the most structurally influential ones. Its originality lies in consolidating diverse human factors into distinct categories and ranking them through frequency and centrality, offering a systems perspective beyond traditional analyses.

Keywords Lean construction, Scheduling, Human factors, Network analysis, Interrelationships

Paper type Research article

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1. Introduction

The construction sector is a cornerstone of global economic growth, contributing about 13% to global GDP and generating annual spending of nearly USD 10 trillion, projected to reach USD 14 trillion by 2025 (Mc Kinsey Global Institute, 2017). Despite its large scale, the industry continues to lag behind other sectors in productivity, with annual growth averaging only 1% compared to 3% in manufacturing (McKinsey Global Institute, 2024). As global demand for infrastructure, housing, and sustainable development intensifies, these inefficiencies create pressure to adopt innovative and waste-reducing practices (Weerapura *et al.*, 2023). In New Zealand, the construction industry mirrors these global trends but faces additional local constraints. It contributes 6.3% to GDP and employs over 10% of the national workforce (MBIE, 2024). Yet productivity remains low due to factors such as housing markets and reliance on imported materials (Kirby *et al.*, 2024). Further challenges include an ageing workforce and a persistent shortage of skilled labour (Kirby *et al.*, 2025). These systemic pressures underscore the need for lean construction methods, which have shown significant benefits internationally but remain slow to be adopted and inconsistent in New Zealand, largely due to persistent human-related barriers.

Lean construction emerged in response to inefficiencies and cost overruns in project delivery (González *et al.*, 2022). Its principles focus on maximising value for the client by eliminating non-value-adding activities, improving workflow reliability, and fostering collaboration among project stakeholders (Katō and Smalley, 2011). Internationally, lean methodologies such as the Last Planner System (LPS) and takt time planning have reported improvements of up to 25% in cost efficiency compared to traditional project management practices (Hasan *et al.*, 2018). These approaches rely not only on technical scheduling tools but also on teams' collective commitment to honouring work promises, communicating effectively, and continuously improving performance (Warid and Hamani, 2023). In practice, however, lean construction often faces obstacles when applied outside of manufacturing because construction projects are temporary, involve multiple stakeholders with competing interests, and operate under uncertain site conditions. Tezel *et al.* (2018) note that lean is sometimes adopted superficially under client pressure, leading to inefficiencies and disillusionment. Similarly, Vecchio *et al.* (2023) emphasise that early collaboration and stakeholder engagement are crucial to project success, yet fragmented supply chains frequently undermine these practices.

A critical dimension of lean construction is the influence of human factors on scheduling practices. While many studies have focused on the technical application of lean tools, less attention has been given to how behavioural, organisational, and cultural variables shape implementation outcomes. Hughes and Thorpe (2014) argue that workforce resistance to change and insufficient training frequently derail lean initiatives, while Likita *et al.* (2024) highlight that poor teamwork and communication exacerbate waste and inefficiency. Kirby *et al.* (2025) further stress that weak leadership commitment and conservative attitudes towards innovation continue to hinder lean adoption in New Zealand. These findings reveal a significant gap in the literature: existing research often treats lean scheduling inefficiencies as technical issues, rather than recognising the systemic role of human barriers (Hasan *et al.*, 2018; Kirby *et al.*, 2024; Likita *et al.*, 2024; Magnani *et al.*, 2023). The consequence is that lean construction efforts frequently fail to realise their full potential, as individuals' behaviours, skills, and attitudes remain misaligned with the collaborative norms required for success.

This study directly addresses that gap by focusing on the human-related variables that affect lean construction scheduling in New Zealand. By analysing these human-centric challenges, the research aims to provide practical insights into how lean scheduling can be better adapted to local realities. The guiding research question is: What are the human factors affecting the efficiency of lean scheduling in the New Zealand construction industry, and what actions can be recommended to reduce their impact? Addressing this question not only contributes to the academic understanding of lean construction but also offers actionable strategies for industry stakeholders seeking to enhance productivity, reduce waste, and strengthen project performance.

2. Literature review

The construction sector is vital to New Zealand's economy, accounting for 6.3% of GDP and employing more than 10% of the national workforce in 2023 (MBIE, 2024). Despite its importance, productivity remains low, with growth rates consistently lagging behind the OECD average (Curtis, 2018; New Zealand Productivity Commission, 2023). These challenges have intensified calls for innovative approaches to improve performance, with lean construction increasingly recognised as a viable solution (Kirby *et al.*, 2024). Derived from the Toyota Production System, lean construction provides a structured framework to minimise waste, enhance workflow reliability, and strengthen collaboration (González *et al.*, 2022; Likita *et al.*, 2024). Techniques such as the Last Planner System and takt time planning have demonstrated substantial gains, including a 54% productivity improvement and early project completion in case studies (Johansen *et al.*, 2021). Beyond efficiency, lean promotes safety, trust, and continuous improvement across project teams (Power *et al.*, 2024; Sarhan *et al.*, 2019). However, in New Zealand, adoption remains fragmented due to skill shortages, limited workforce capability, and cultural resistance to change, leading to partial implementation and reduced benefits (Tezel *et al.*, 2018).

Several studies point to the persistent inefficiency of lean implementation in practice. Despite its theoretical promise, lean construction has not delivered consistent productivity gains across the sector, particularly in regions like New Zealand, where output has fluctuated, with construction's GDP contribution falling from 6.3% to 4.4% in 2023 (MBIE, 2024). Globally, construction productivity has remained stagnant since the mid-twentieth century, even as manufacturing and agriculture achieved transformative gains (Mc Kinsey Global Institute, 2017). Scholars emphasise that many of these shortcomings are linked not to the lean framework itself, but to barriers to its application, including weak leadership commitment, ineffective integration across supply chains, and insufficient workforce capability (Kirby *et al.*, 2025; Likita *et al.*, 2024). These observations suggest that while lean scheduling tools have proven technical value, their success depends on addressing the human and organisational conditions in which they are embedded. As such, research attention has increasingly shifted toward understanding the specific factors that hinder or enable lean scheduling performance.

Among the most critical influences are human-related factors. Studies identify multiple dimensions, including knowledge and skill, behaviour and attitude, communication and collaboration, and decision-making. Skill shortages, an ageing workforce, and insufficient training limit the industry's ability to adapt to new technologies and processes (Chen *et al.*, 2023; Uhrin *et al.*, 2017). Without adequate training, resistance to lean tools is common, as observed in Brazil, Lebanon, and other contexts (De Silva *et al.*, 2025; Hamzeh and Albanna, 2019). Behavioural and cultural factors further complicate implementation, with low motivation, adversarial team cultures, and resistance to change frequently undermining collaboration (Evans and Farrell, 2021; Sarhan *et al.*, 2019; Ugurlu *et al.*, 2021). Poor communication and weak collaboration are repeatedly cited as global barriers that contribute to rework, safety issues, and significant productivity losses (Bayhan *et al.*, 2019; Demirkesen and Bayhan, 2020; Yang *et al.*, 2020). Finally, decision-making processes, which are often constrained by cognitive biases, limited information, or time pressures, can generate waste and heighten risks on site (Purushothaman and Seadon, 2024). While these variables are widely acknowledged in international studies, their interplay within the New Zealand context remains underexplored.

In summary, the literature demonstrates that lean construction has the potential to transform project delivery by reducing waste, enhancing workflow, and fostering collaboration. However, evidence also reveals persistent inefficiencies linked to human factors, such as ineffective training, workforce ageing, a conservative attitude, and poor communication. Although these challenges have been investigated in global studies (Chen *et al.*, 2023; Enshassi *et al.*, 2021; Magnani *et al.*, 2023), there remains limited research examining their specific influence on lean scheduling within the New Zealand construction industry. This gap is significant given New Zealand's unique demographic profile, small and fragmented market, and reliance on imported labour and materials. Addressing this research gap is crucial to understanding how behavioural dynamics shape the implementation of lean scheduling locally, and to developing targeted strategies that can support contractors, consultants, and subcontractors in overcoming these barriers and improving project efficiency.

3. Methodology

3.1 Research design

This study employed a qualitative research design that integrated a systematic literature review (SLR) with expert validation to examine people-centred factors affecting lean construction scheduling. The SLR, conducted in accordance with PRISMA guidelines (Page *et al.*, 2021), ensured methodological transparency and rigour. Seventy-seven peer-reviewed studies published after 2020 were reviewed and thematically coded into eight categories: awareness, behaviour, collaboration, communication, decision making, organisation, skills, and training. The selected studies were sourced internationally and were not limited to the New Zealand context, ensuring that the identified human factors reflect globally reported lean construction challenges. Network analysis further enhanced the process by analysing frequency through an author–factor matrix, identifying key influences using eigenvector and degree of centrality measures, and visualising systemic relationships through causal loop diagrams. To validate and contextualise these findings, semi-structured interviews were held with five experienced professionals from New Zealand's construction industry. Their insights confirmed the relevance of key factors and provided context-specific understanding of how these human elements influence lean scheduling efficiency. Table 1 summarises the data sources, collection methods, and analytical approaches adopted in this study.

3.2 Secondary data collection (SLR)

A systematic literature review (SLR) was undertaken as the primary strategy for collecting secondary data on human factors affecting lean construction scheduling. The review process began with the development of a keyword framework based on four pillars: lean construction, human involvement, influencing factors, and the construction context. Synonyms and Boolean operators were used to create search strings executed across Scopus, ScienceDirect, and EBSCOhost, following defined inclusion and exclusion criteria. Table 2 summarises the search strategy and results. A total of 604 publications were retrieved, of which 77 met the selection criteria and were analysed in detail. These studies provided the foundation for

Table 1. Summary of data collection and analysis methods

S/N	Research data	Collection method	Research analysis methods
1	*Secondary Data* Peer-reviewed journal articles, conference papers, and academic publications	*Systematic Literature Review (SLR)*	*Biblometric Analysis* (mapping research trends and influential publications) *Thematic Analysis* (identifying recurring themes and research gaps)
2	*Primary Data* Industrial experiences and perspectives of construction professionals in New Zealand	*Semi-Structured Interviews* Narrative enquiry and open ended question	*Narrative Analysis* (interpreting participants' lived experiences) *Thematic Analysis* (extracting common patterns and key issues across narratives)

Source(s): Authors' own work

Table 2. Database search strategy and results

Database	Search string	Inclusion	Exclusion
Scopus	("Lean Construction" OR "Lean Management" OR "Lean Enterprise" OR "Lean Thinking") AND (Factor* OR Barrier* OR Challenge* OR Influence*) AND (Construction OR Building Or Engineering)	2020–2025, English, journal and conference papers, engineering and management subject areas	Non-English, before 2020, reviews, irrelevant subject categories
ScienceDirect	("Lean Construction" OR "Lean Management" OR "Lean Thinking") AND ("Human factor" OR Barriers OR Challenges OR "Human impact") AND (Construction)	2020–2025, English, engineering, peer-reviewed research articles	Non-English, before 2020, reviews, conference papers
EBSCO	("Lean Construction" OR "Lean Management" OR "Lean Thinking") AND ("Human factor" OR Barriers OR Challenges OR "Human impact") AND (Construction)	Past 5 years, English, peer-reviewed, full text, lean construction and project-focused publications	Non-English, older than 5 years, reviews, conference papers

Source(s): Authors' own work

identifying and consolidating human-related factors, which were later examined through thematic and network analysis.

3.2.1 Prisma flow Chart and data extraction. The combined database searches yielded 604 records, of which 116 duplicates were removed, leaving 488 unique studies for screening. Titles and abstracts were reviewed against the inclusion criteria, leading to the exclusion of 341 records that were not directly related to lean construction or human barriers. The remaining 147 articles were retrieved in full text and assessed for eligibility. Seventy of these were excluded because they either lacked methodological rigour, addressed technical scheduling models without human-related analysis, or were outside the construction sector. This process resulted in a final set of 77 studies that were included in the systematic review. The selection pathway is illustrated in the PRISMA flow diagram (Figure 1), which shows the progressive refinement of records across the identification, screening, and inclusion stages.

3.2.2 Data extraction and recording. After screening, data from 77 selected studies were systematically extracted to identify human factors influencing lean construction scheduling. Bibliographic details such as author, year, and country were recorded in Microsoft Excel for reference management. Each article was reviewed in full, and relevant text relating to human or behavioural factors was highlighted using EndNote 21, as shown in Figure 2. The extracted data were organised into five columns, recording the factor, description, author's stance, page number, and article ID. This process produced 615-factor entries, forming a structured foundation for subsequent thematic and network analysis.

A "factor" was defined as any explicitly stated human-related barrier, enabler, or behavioural condition influencing lean construction or scheduling performance. During extraction, semantically similar expressions (e.g. "lack of training" and "insufficient lean education") were recorded separately to preserve the original author's intent. Consolidation into 54 categories was conducted through iterative thematic comparison, in which conceptually overlapping items were merged based on their shared underlying meaning rather than on wording similarity. To enhance coding reliability, extracted items were re-reviewed and cross-checked against original sources to ensure conceptual consistency prior to aggregation.

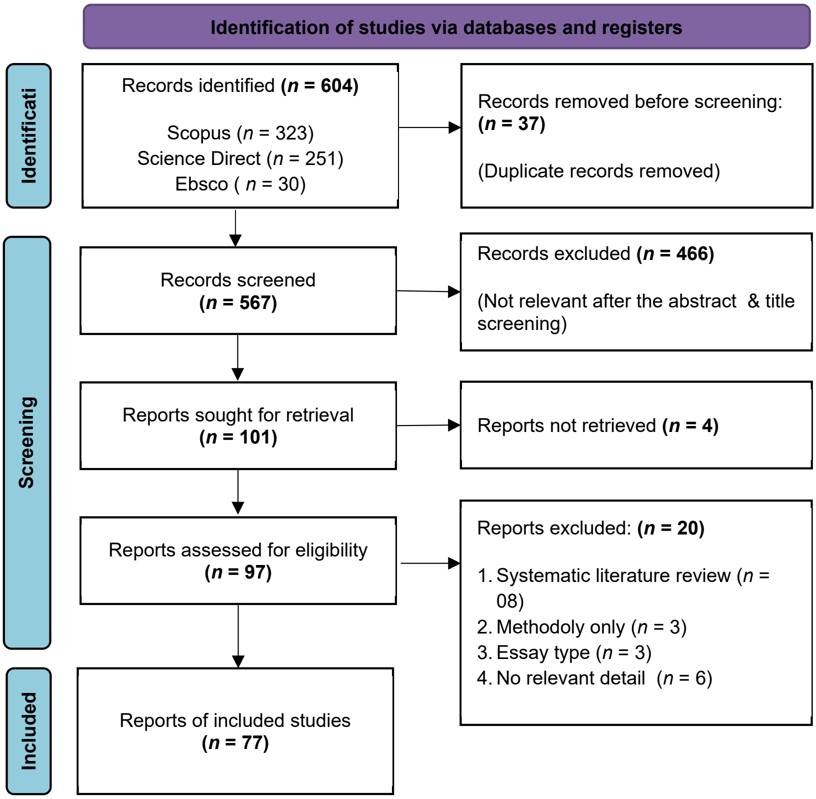

Figure 1. Prisma flow diagram. This work is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/. Page *et al.* (2021)

3.2.3 Thematic analysis, coding, and pattern identification. The recorded data from 615 entries were organised and categorised through thematic analysis to identify recurring patterns among human aspects affecting lean construction scheduling. Each factor was coded and grouped into one of eight themes, with overlapping or duplicated terms standardised for consistency. This process refined the dataset to 54 unique factors, each assigned a thematic code for analysis. Relationships between factors were then examined to determine influence and polarity, defined as positive, negative, or neutral, as shown in Figure 3. These structured relationships served as the foundation for subsequent network and causal loop analyses.

3.2.4 Data analysis tools and process. The previously coded data, together with the developed author–factor matrix and interrelationship matrix, were used for network and system analysis. Vensim software was used to generate the causal loop diagram and calculate centrality, enabling visualisation of the dynamic relationships among factors. Gephi software was then used to compute eigenvector centrality, identifying the most influential nodes within the network. Together, these analytical tools provided a comprehensive understanding of how human factors interact and shape lean construction scheduling efficiency.

3.3 Expert interview for data validation

Expert interviews were conducted to complement the systematic literature review and provide contextual support for the findings within the New Zealand construction context. The aim was to confirm whether the most influential behavioural factors identified through the SLR align

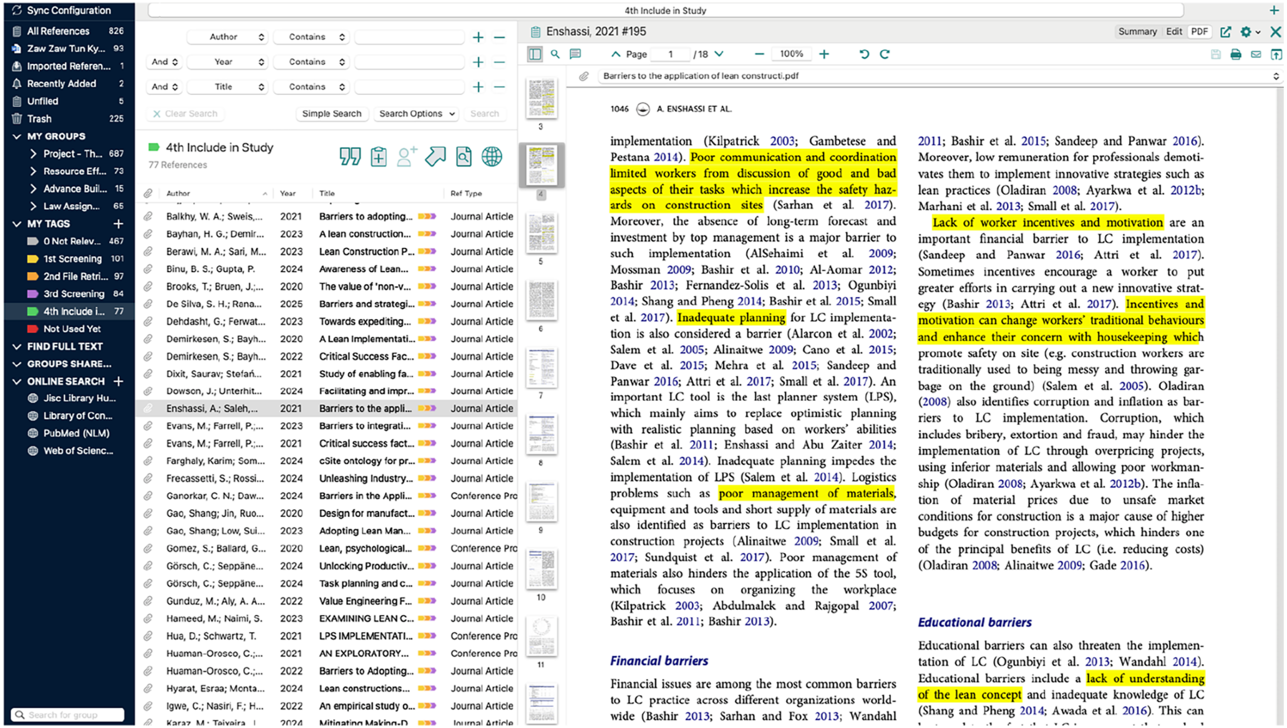

Figure 2. Data screening using endnote. Authors' own work using EndNote 21 software

Article Number	Title	Author	Year	Factor A	Factors (A)	Factor B	Polarity	Page No	Para No
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	S03	Inadequate Skilled Workforce		None		
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	C01	Lack of Respect & Trust		None		
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	T03	Lack of Continuous Lean Training	A01	Positive	6	3
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	S02	Inadequate Technical Skill	A02	Positive	7	1
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	A02	Inadequate Technical Knowledge		None		
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	T04	Lack of Skill Related Training	S02	Positive	7	1
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	T04	Lack of Skill Related Training	S03	Positive	7	1
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	A01	Inadequate Conceptual Knowledge		None		
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	T03	Lack of Continuous Lean Training	A01	Positive	6	3
1	The barriers of the implementati	Ahmed, M.; E. A.; Wong,	2020	CM03	Ineffective Communication Among Team Members		None		
2	Students' perception of strategi	Aka, A.; Isah, A. D.; Salis	2023	A01	Inadequate Conceptual Knowledge		None		
2	Students' perception of strategi	Aka, A.; Isah, A. D.; Salis	2023	T02	Lack of Conceptual Awareness Programs	A01	Positive	3	4
2	Students' perception of strategi	Aka, A.; Isah, A. D.; Salis	2023	C04	Ineffective Planning		None		
3	Exploring factors for implement	Aslam, Mughees; Gao, Z	2020	C01	Lack of Respect & Trust	C03	Positive	3	2
3	Exploring factors for implement	Aslam, Mughees; Gao, Z	2020	O01	Inadequate Motivation or Incentives		None		
3	Exploring factors for implement	Aslam, Mughees; Gao, Z	2020	C03	Inadequate Collaboration Between Skateholders		None		
3	Exploring factors for implement	Aslam, Mughees; Gao, Z	2020	T03	Lack of Continuous Lean Training	A01	Positive	3	5
3	Exploring factors for implement	Aslam, Mughees; Gao, Z	2020	A02	Inadequate Technical Knowledge		None		
3	Exploring factors for implement	Aslam, Mughees; Gao, Z	2020	O05	Inadequate Engagement from Skateholders	C03	Positive	3	3
3	Exploring factors for implement	Aslam, Mughees; Gao, Z	2020	D05	Poor Decision-Making Due to Inadequate Knowledge		None		
3	Exploring factors for implement	Aslam, Mughees; Gao, Z	2020	T04	Lack of Skill Related Training	A02	Positive	3	5
3	Exploring factors for implement	Aslam, Mughees; Gao, Z	2020	A01	Inadequate Conceptual Knowledge		None		
4	Driving factors for lean-BIM imp	Aziz, N. M.; Zainon, N.	2023	O05	Inadequate Engagement from Skateholders		None		
4	Driving factors for lean-BIM imp	Aziz, N. M.; Zainon, N.	2023	O04	Cultural Resistance to Change		None		
4	Driving factors for lean-BIM imp	Aziz, N. M.; Zainon, N.	2023	S03	Inadequate Skilled Workforce	S02	Positive	881	6
4	Driving factors for lean-BIM imp	Aziz, N. M.; Zainon, N.	2023	B04	Individual's Resistance to Change		None		
4	Driving factors for lean-BIM imp	Aziz, N. M.; Zainon, N.	2023	T04	Lack of Skill Related Training	B04	Positive	882	2
4	Driving factors for lean-BIM imp	Aziz, N. M.; Zainon, N.	2023	C03	Inadequate Collaboration Between Skateholders		None		

Figure 3. Interrelationships and polarity among factors. Authors' own work

with industry practice. Five experts were purposively selected, each with over five years of experience and direct involvement in lean construction. Participants were recruited through academic and professional networks and provided with information on confidentiality. Interviews were conducted online via Microsoft Teams using a semi-structured format, lasting 20–40 minutes. All sessions were recorded with consent, transcribed, anonymised, and securely stored in AUT OneDrive. As presented in Table 3, the participants represented a balanced mix of academia and industry, including lecturers, researchers, engineers, and senior managers. Although the sample size was limited to five participants, purposive selection prioritised depth of lean construction experience over numerical breadth. The interviews provided contextual alignment with the literature-derived findings and helped assess their practical resonance within the New Zealand setting.

4. Data analysis and result

This section presents the analytical results from the systematic literature review and thematic coding of 54 unique human variables influencing lean construction scheduling. The analysis interprets structured data to examine interrelationships, frequencies, and influence pathways among factors. Using narrative interpretation, matrix mapping, and systems-thinking tools, it provides a comprehensive understanding of how human variables shape lean scheduling performance. The author–factor and interrelationship matrices, provided in the appendix 1 and 2, formed the analytical foundation. Frequency analysis identified dominant themes, while causal loop and centrality measures highlighted key influential factors. Eigenvector centrality further revealed systemic importance. Expert validation complements these findings with practical industry perspectives.

4.1 Annual distribution of articles by countries

Figure 4 illustrates the annual distribution of publications between 2020 and 2025. In terms of overall contributions, the United States leads with 7 articles, followed by the United Kingdom and India with 6 each. Other regular contributors include Australia, China, Malaysia, and New Zealand. Countries with 1–2 publications were grouped under “Others,” which includes Brazil, Colombia, Egypt, Finland, Jordan, Qatar, Singapore, and Turkey, with 2 each, alongside 15 nations with 1 each, such as Canada, Chile, Ethiopia, Ghana, and Vietnam. This distribution highlights both the growing interest in lean construction research and its global diversity, though it is concentrated in a smaller number of leading countries.

4.2 SLR frequency

This analysis examined how often each human factor appeared across the reviewed literature to highlight those most commonly recognised in lean construction research. Using the Author–Factor Matrix, 54 unique factors were evaluated across 77 studies and ranked by frequency. The most cited factor was Inadequate Conceptual Knowledge (A01), appearing in 42 studies, followed by Cultural Resistance to Change (O04, 31 mentions), Lower Motivation and

Table 3. Demographic profile of participants

Code	Current role	Organisation type	Years of experience	Interview date
P1	Assistant Lecturer	Academia	7	14 Aug 2025
P2	Project Manager	Private Contractor	10	22 Aug 2025
P3	Planning Engineer	Main Contractor	5	29 Aug 2025
P4	General Manager	Private Contractor	21	4 Sept 2025
P5	Lean Research Expert	Academia	9	16 Sept 2025

Source(s): Authors’ own work

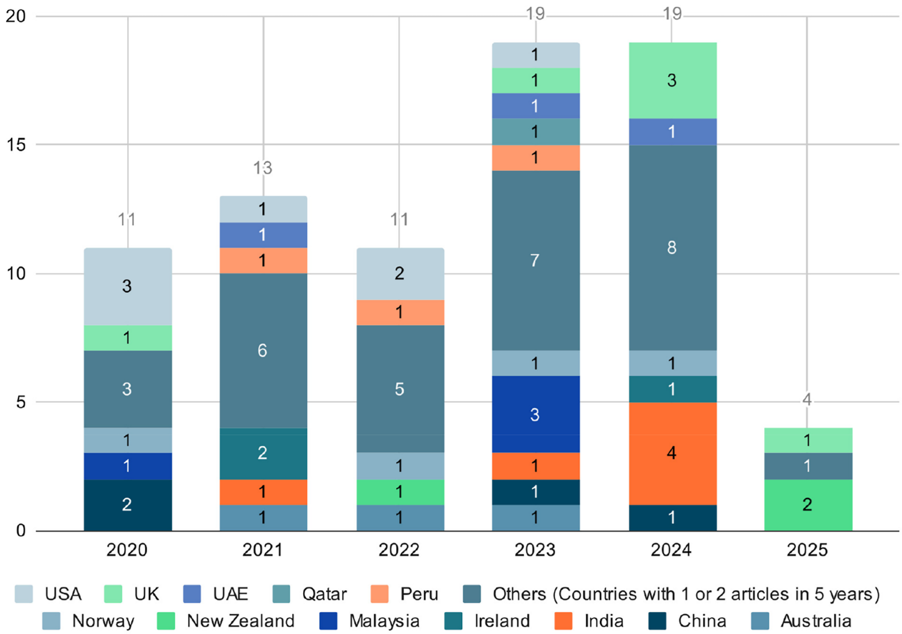

Figure 4. Annual distribution of articles by country. Authors' own work

Engagement (B05, 28 mentions), and Lack of Continuous Lean Training (T03, 28 mentions). These reflect recurring organisational, cultural, and skill-related barriers. At the lower end, factors such as CM05 and D03 were mentioned only once, though they may still hold contextual relevance as shown in Table 4 below.

4.3 Causal loop diagram and degree of centrality

A causal loop diagram (CLD) was developed using Vensim software to examine the systemic interactions among behavioural factors. As shown in Figure 5, the diagram illustrates how 54 generalised factors interact through 294 directional linkages, forming a dense network of reinforcing relationships. Based on these mapped relationships, the degree of centrality was calculated to determine the most structurally influential factors. Centrality measures the importance of each factor by assessing its number of incoming and outgoing links, revealing leverage points where interventions can create broader system-wide improvements (Bamakan *et al.*, 2019). The results (Table 5) show "Lower Motivation and Engagement" (B05) and "Inadequate Top Management Support" (O03) as the most central, followed by "Cultural Resistance to Change" (O04) and related collaboration factors.

Network edges represent co-occurrence relationships identified within the reviewed studies, indicating conceptual association rather than causal dependency. Centrality measures were employed to assess structural prominence within this conceptual network, identifying factors occupying influential positions within the interconnected structure. While frequency reflects regularity in literature, centrality captures the quality of relationships, thereby reducing the risk of equating popularity with systemic influence.

4.4 Eigenvector centrality

Eigenvector centrality is a robust metric in network analysis that identifies the most influential nodes in a system by considering not just the number of connections or degree of a node, but

Table 4. Frequency of factors identified in the SLR

S/N	Code	Factors	Frequency	Rank
1	A01	Inadequate Conceptual Knowledge	42	#1
2	O04	Cultural Resistance to Change	31	#2
3	B05	Lower Motivation and Engagement	28	#3
4	T03	Lack of Continuous Lean Training	28	#3
5	C03	Inadequate Collaboration Between Stakeholders	27	#4
6	O03	Inadequate Commitment and Support from Top Management	27	#4
7	B04	Individual's Resistance to Change	26	#5
8	B03	Conservative and Negative Attitude	23	#6
9	O05	Inadequate Engagement from Stakeholders	20	#7
10	A02	Inadequate Technical Knowledge	18	#8
11	CM01	Inadequate Information Exchange Among Stakeholders	17	#9
12	B08	Poor Leadership	16	#10
13	S03	Inadequate Skilled Workforce	16	#10
14	C01	Lack of Respect and Trust	15	#11
15	CM03	Ineffective Communication Among Team Members	15	#11
16	S02	Inadequate Technical Skill	15	#11
17	D05	Poor Decision-Making Due to Inadequate Knowledge	14	#12
18	B09	Lack of Commitment	13	#13
19	S01	Lack of Lean Expert	13	#13
20	O02	Absence of Lean Culture	12	#14
21	O01	Inadequate Motivation or Incentives	11	#15
22	T02	Lack of Conceptual Awareness Programs	11	#15

Source(s): Authors' own work

also the importance of the nodes it is connected to (Bienenstock and. Unlike degree centrality, which treats all connections equally, eigenvector centrality gives more weight to links connected to already well-connected nodes.

Based on the interrelationship matrix developed in the previous section, eigenvector centrality values were calculated using Gephi 0.10, which is a specialised network visualisation and analysis tool (https://gephi.org/). The output was normalised using the following formula:

$$\mathrm{Norm}\,(\mathrm{Magnitude}) = \sqrt{(x_1^2 + x_2^2 + \ldots + x_n^2)}$$

The results were used to rank the most influential factors within the system, as shown in Table 6. These findings are visually represented in Figure 6, where the node size reflects the relative centrality score. The larger the node, the more structurally influential the factor is in the network.

4.5 Loop analysis

To explore how human barriers interact systemically, a loop cycle analysis was performed using the causal loop diagram results. Unit weight measures the number of unique factors in each loop, while centrality weight reflects how structurally influential the loop is. The results, summarised in Table 7, show that Loops 1 and 2 contain the most factors (21 each), followed by Loops 3 and 4 (20 each). Loop 3 achieved the highest centrality score of 11.27, dominated by critical factors such as lower motivation (B05), weak management support (O03), and inadequate training (T03). High-weight loops demonstrate how inefficiencies reinforce each other, while lower-weight loops reveal localised behavioural issues and potential leverage points for intervention within lean construction systems.

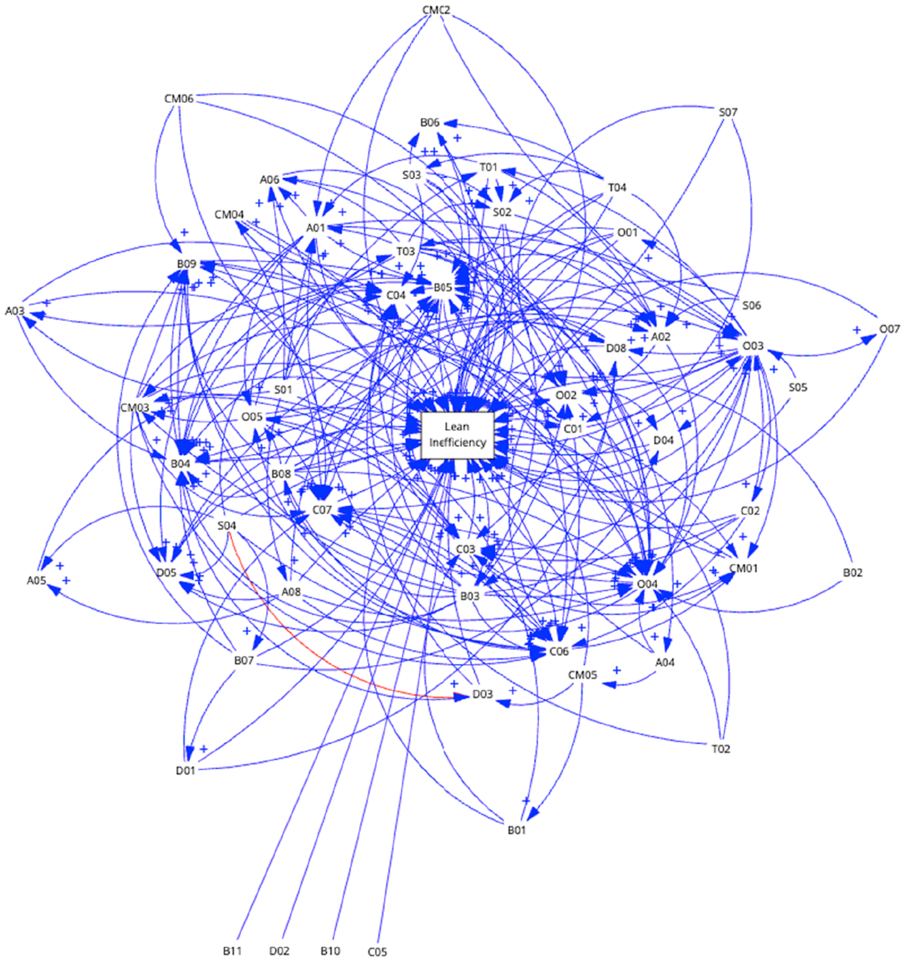

Figure 5. Causal loop diagram. Authors' own work using Vensim Software

4.6 Expert interview data validation

As shown in Table 8, collaboration, leadership support, and motivation were the most frequently emphasised by participants. The other three factors, inadequate conceptual knowledge, conservative attitude, and cultural resistance to change, were also highlighted, though with slightly less frequency, confirming their ongoing significance in practice. These results indicate that the human barriers identified through global research are also visible in the New Zealand context.

5. Discussion

This section interprets the findings by focusing on the human factors that most strongly influence inefficiencies in lean construction scheduling. Drawing on results from the systematic literature review, degree of centrality, interrelation mapping, and expert validation, the analysis identifies factors with both academic and practical significance in the New

Table 5. Degree of centrality ranking table

Code	Factors	Out-degree	In-degree	Total degree	Degree of centrality	Rank
B05	Lower Motivation and Engagement	6	16	22	1.00	#1
O03	Inadequate Commitment and Support from Top Management	15	7	22	1.00	#1
O04	Cultural Resistance to Change	3	17	20	0.91	#2
C06	Lack of Effective Teamwork	2	12	14	0.64	#3
C07	Inadequate Internal Collaboration	2	12	14	0.64	#3
B03	Conservative and Negative Attitude	12	2	14	0.64	#3
A01	Inadequate Conceptual Knowledge	8	5	13	0.59	#4
C03	Inadequate Collaboration Between Stakeholders	4	9	13	0.59	#4
B04	Individual’s Resistance to Change	3	10	13	0.59	#4
B09	Lack of Commitment	5	8	13	0.59	#4
C01	Lack of Respect and Trust	10	2	12	0.55	#5
B08	Poor Leadership	11	1	12	0.55	#5
T03	Lack of Continuous Lean Training	8	3	11	0.50	#6
O02	Absence of Lean Culture	3	8	11	0.50	#6
O05	Inadequate Engagement from Stakeholders	6	4	10	0.45	#7
C04	Ineffective Planning	0	10	10	0.45	#7
CM03	Ineffective Communication Among Team Members	6	4	10	0.45	#7
A02	Inadequate Technical Knowledge	3	6	9	0.41	#8
D05	Poor Decision-Making Due to Inadequate Knowledge	1	6	7	0.32	#9
S01	Lack of Lean Expert	7	0	7	0.32	#9
D08	Lack Of Time	4	3	7	0.32	#9
S02	Inadequate Technical Skill	2	4	6	0.27	#10
S03	Inadequate Skilled Workforce	5	1	6	0.27	#10
S04	Lack of Experience	6	0	6	0.27	#10
CM01	Inadequate Information Exchange Among Stakeholders	2	4	6	0.27	#10
A08	Lack of Standerdised Knowledge	5	1	6	0.27	#10

Source(s): Authors’ own work

Zealand context. A comparative assessment was conducted using three analytical dimensions: SLR frequency, degree of centrality, and eigenvector centrality. This multi-layered approach highlights not only how frequently each factor appears in the literature but also its structural importance within the interconnected network of human barriers. Table 9 summarises the comparative results, showing the top-ranked factors across all three measures.

Six factors emerged as the most critical contributors to lean scheduling inefficiencies: lower motivation and engagement (B05), inadequate collaboration between stakeholders (C03), inadequate commitment and support from top management (O03), cultural resistance to change (O04), conservative and negative attitude (B03), and inadequate conceptual knowledge (A01). Their consistent appearance across multiple analyses indicates that inefficiencies in lean scheduling arise from complex human interactions rather than isolated issues. Together, these six factors provide the foundation for developing targeted strategies to enhance the application of lean in New Zealand.

The core network structure was derived from a global systematic literature review, indicating that the identified patterns reflect internationally recognised lean construction challenges. The New Zealand interviews provided contextual validation, suggesting that the findings are transferable to similar project-based construction markets.

Table 6. Eigenvector centrality ranking

Code	Factors	Eigenvector centrality	Normalised value (centrality/Norm)	Rank
B05	Lower Motivation and Engagement	1.000	0.380	#1
O04	Cultural Resistance to Change	0.924	0.351	#2
O03	Inadequate Commitment and Support from Top Management	0.840	0.319	#3
B03	Conservative and Negative Attitude	0.779	0.296	#4
C07	Inadequate Internal Collaboration	0.696	0.265	#5
B08	Poor Leadership	0.655	0.249	#6
B09	Lack of Commitment	0.612	0.233	#7
C01	Lack of Respect and Trust	0.598	0.228	#8
A01	Inadequate Conceptual Knowledge	0.594	0.226	#9
C03	Inadequate Collaboration Between Stakeholders	0.577	0.220	#10
O02	Absence of Lean Culture	0.571	0.217	#11
C06	Lack of Effective Teamwork	0.552	0.210	#12
O05	Inadequate Engagement from Stakeholders	0.549	0.209	#13
CM03	Ineffective Communication Among Team Members	0.499	0.190	#14
B04	Individual's Resistance to Change	0.484	0.184	#15
	Norm (Magnitude)		2.6293	

Source(s): Authors' own work

5.1 Key human factors affecting lean construction

Lower Motivation and Engagement (B05): Motivation is central to lean practices such as the Last Planner System (LPS), which depend on active participation. However, perceived complexity and meeting fatigue often lead to disengagement, weakening collaboration (Hua and Schwartz, 2021). Motivation drives proactive behaviours like risk anticipation and constraint management (Power *et al.*, 2024). Strategies such as linking promotions or recognition to lean achievements can enhance engagement (Likita *et al.*, 2025). As one expert noted, "The challenge is not only about the tools but about how motivated people are to use them" (P2). Therefore, sustaining motivation is crucial for transforming lean practices into a shared mindset that drives continuous improvement.

Inadequate Collaboration Between Stakeholders (C03): Effective collaboration among contractors, consultants, and suppliers underpins lean success. Poor collaboration disrupts workflows and reduces trust. Studies show that LPS enhances coordination (Bajjou and Chafi, 2022) and that interdepartmental cooperation improves project efficiency (Berawi *et al.*, 2023). Conversely, fragmentation and misaligned goals increase inefficiencies (Hyarat *et al.*, 2024). Experts reinforced that collaboration forms "the people side of lean pillars" (P1). In short, it acts as a systemic barrier that weakens trust, disrupts coordination, and prevents lean construction from achieving its full efficiency potential.

Inadequate Commitment and Support from Top Management (O03): Leadership commitment determines whether lean initiatives are sustained or superficial. Without consistent management support, motivation and accountability weaken (Hughes and Thorpe, 2014). Visible leadership engagement through resources, follow-ups, and cultural endorsement enhances adoption (Likita *et al.*, 2024). Expert feedback confirmed that strong managerial backing is essential for maintaining site-level enthusiasm and embedding lean culture. Hence, it weakens the cultural and motivational foundations of lean, highlighting that sustained leadership commitment is crucial. These findings are also consistent with broader organisational and leadership research, which emphasises the central role of culture and managerial commitment in shaping behavioural change within complex project environments.

Cultural Resistance to Change (O04): Cultural inertia and adversarial traditions remain major barriers to lean transformation. Research across China, Turkey, and the Middle East

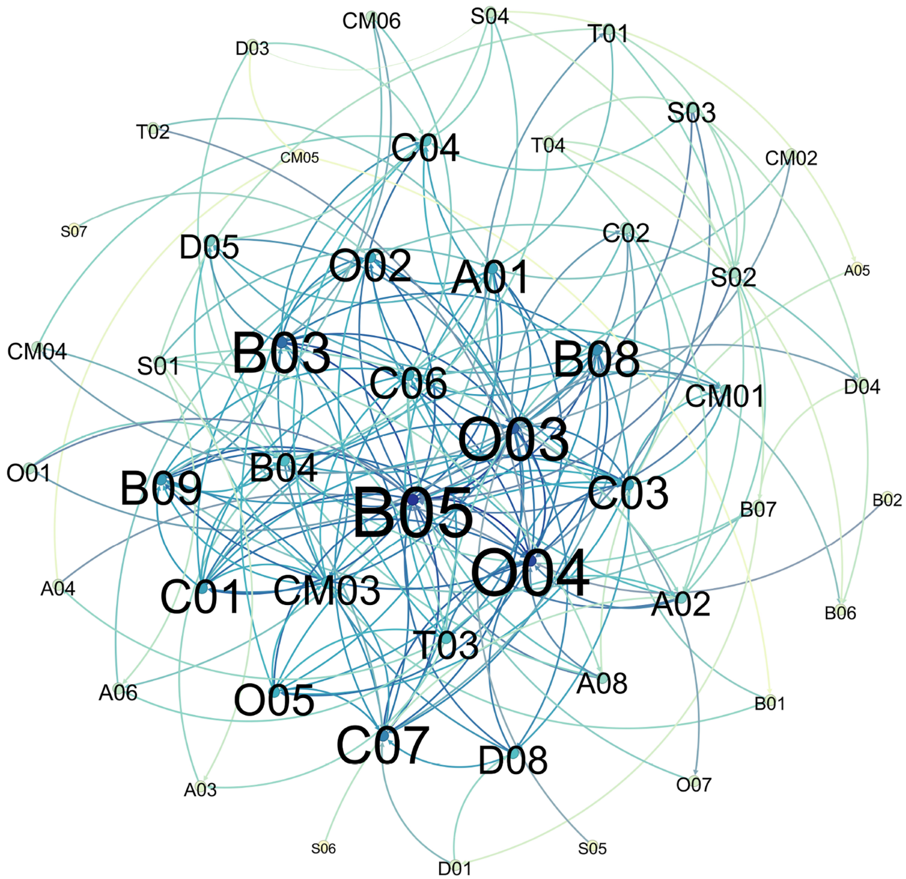

Figure 6. Eigenvector centrality network graph. Authors' own work using Gaphi Software

links hierarchical and conservative work cultures to limited lean adoption (Bayhan *et al.*, 2023; Ugurlu *et al.*, 2021). Similar patterns exist in New Zealand, where ingrained habits and scepticism toward new methods continue to impede change. Therefore, cultural resistance reinforces traditional practices and obstructs innovation, and thereby acts as a major barrier to cultural transformation.

Conservative and Negative Attitude (B03): At the individual level, conservative mindsets restrict innovation and openness to new tools (Kirby *et al.*, 2025). Negative perceptions of lean can lead to disengagement, preventing systems such as LPS from achieving their full benefits (Sarhan *et al.*, 2019). Experts emphasised that entrenched attitudes among senior staff often slow progress. In short, this factor creates behavioural rigidity that limits adaptability, open-mindedness, and continuous learning within lean teams.

Inadequate Conceptual Knowledge (A01): A limited understanding of lean concepts reduces the effectiveness of implementation. Insufficient training creates confusion and resistance (De Silva *et al.*, 2025; Hamzeh and Albanna, 2019). Knowledge-sharing across teams enhances collective capability (Chen *et al.*, 2023; Malvik *et al.*, 2024). Expert interviews confirmed ongoing conceptual gaps in New Zealand's workforce, underscoring the need for structured lean education. Therefore, this factor prevents teams from translating lean theory into effective practice, making targeted education and knowledge exchange essential.

Table 7. Key feedback loops with unit and centrality weight

	Loop cycle	Unit weight	Unit weight rank	Centrality weight	Centrality weight rank
1	C01 → O02 → O04 → C03 → O05 → T03 → A04 → CM05 → B01 → CM03 → D05 → O03 → D08 → B03 → B08 → B04 → B09 → C07 → C06 → CM01 → B05 → C01	21	#1	10.91	#3
2	C01 → O02 → O04 → B09 → C07 → C06 → CM01 → C03 → O05 → T03 → A04 → CM05 → B01 → CM03 → D05 → O03 → D08 → B03 → B08 → B04 → B05 → C01	21	#1	10.91	#3
3	C01 → CM03 → D05 → O03 → D08 → B03 → B08 → C07 → C06 → CM01→ C03 → O05 → T03 → A01 → A06 → O02 → O04 → B09 → B04 → B05 → C01	20	#2	11.27	#1
4	T03 → A04 → CM05 → B01 → CM03 → D05 → O03 → T01 → S02 → A02 → O02 → O04 → B09 → B04 → B05 → C07 → C06 → CM01 → C03 → O05 → T03	20	#2	9.77	#4
5	C01 → CM03 → D05 → O03 → D08 → B03 → B08 → C07 → C06 → CM01 → C03 → O05 → T03 → A01 → O02 → O04 → B09 → B04 → B05 → C01	19	#3	11.09	#2
6	CM03 → D05 → O03 → D08 → B03 → B08 → B04 → B05 → C07 → O04 → B09 → C06 → CM01 → C03 → O05 → CM03	15	–	8.95	–
7	A01 → A06 → O02 → B05 → B04 → B09 → C06 → C07 → O04 → C03 → O05 → CM03 → D05 → O03 → T01 → A01	15	–	8.68	–
8	S02 → A02 → O02 → B05 → B04 → B09 → C06 → C07 → O04 → C03 → O05 → CM03 → D05 → O03 → T01 → S02	15	–	8.59	–
9	A02 → O02 → O04 → B09 → B04 → B05 → C07 → C06 → CM01 → C03 → O05 → CM03 → D05 → O03 → T01 → A02	15	–	8.59	–
10	T03 → A01 → D05 → O03 → T01 → S02 → A02 → B05 → C03 → C06 → C07 → O04 → O05 → T03	13	#Mid Value	7.55	#Mid Value
11	B04 → B09 → C06 → CM01 → B05 → B04	5	–	3.09	–
12	D05 → O03 → D08 → B03 → B08 → D05	5	–	2.82	–
13	C03 → O05 → C07 → C06 → CM01 → C03	5	–	2.59	–
14	O04 → B09 → B05 → C07 → O04	4	–	3.14	–
15	O05 → B05 → C07 → O04 → O05	4	–	3	–
16	B05 → C07 → C06 → CM01 → B05	4	–	2.55	–
17	O03 → D08 → B03 → O03	3	–	1.95	–
18	C03 → C06 → CM01 → C03	3	#Lowest	1.5	#Lowest
19	B03 → B08 → D08 → B03	3	#Lowest	1.5	#Lowest

Source(s): Authors' own work

5.2 Loop dynamics and central feedback structures

Causal loop analysis reveals how behavioural dynamics interact systemically to influence lean construction scheduling. Reinforcing loops illustrate how behavioural barriers such as low motivation, poor communication, and resistance to change compound over time. Loops with the highest unit and centrality weights, particularly Loops 1 to 5, represent the most influential feedback cycles, involving interlinked factors that perpetuate inefficiencies. Six key factors recur across these loops: lower motivation (B05), limited management support (O03), cultural resistance (O04), poor collaboration (C03), conservative attitude (B03), and insufficient conceptual knowledge (A01).

Table 8. Summary of expert validation with SLR findings

Theme / Factor	Mentioned (n = 5)	Alignment with SLR findings	Participant insight
Motivation and Engagement (B05)	5	Aligned – motivation seen as central to lean adoption	*"The challenge is not only about the tools themselves but about how motivated people are to use them . . ."* (P2)
Collaboration (C03)	4	Aligned – collaboration highlighted as essential	*"Collaboration is the key. It is the core of lean construction . . ."* (P1)
Leadership Support (O03)	4	Aligned – leadership commitment viewed as critical	*"Every system implementation . . . requires the full support and commitment from leadership . . ."* (P3)
Cultural Resistance (O04)	5	Aligned – resistance to new practices still prevalent	*"Many experienced people prefer to continue with the methods they already know . . ."* (P3)
Conservative Attitudes (B03)	3	Aligned – hierarchical attitudes seen as barriers	*"We are still stuck with the hierarchy of leadership . . ."* (P5)
Conceptual Knowledge (A01)	3	Aligned – knowledge gaps weaken lean practice	*"Understanding lean principles is very important . . ."* (P1)
Psychological Safety	1	Emergent – highlighted as missing from current factors	*"They may be afraid to be replaced by these new methods and tools . . ."* (P1)
Transformational Leadership	1	Emergent – raised as an additional human factor	*"Transformational leadership encourages lean culture . . ."* (P5)

Source(s): Authors' own work

Table 9. Comparison of top-ranked human factors

Code	SLR Frequency	SLR Rank	Code	Degree of Centrality	DoC Rank	Code	Eigenvector Centrality	EiV Rank
A01	42	#1	B05	1.00	#1	B05	1.000	#1
O04	31	#2	O03	1.00	#1	O04	0.924	#2
B05	28	#3	O04	0.91	#2	O03	0.840	#3
T03	28	#3	C06	0.64	#3	B03	0.779	#4
C03	27	#4	C07	0.64	#3	C07	0.696	#5
O03	27	#4	B03	0.64	#3	B08	0.655	#6
B04	26	#5	A01	0.59	#4	B09	0.612	#7
B03	23	#6	C03	0.59	#4	C01	0.598	#8
O05	20	#7	B04	0.59	#4	A01	0.594	#9
A02	18	#8	B09	0.59	#4	C03	0.577	#10

Source(s): Authors' own work

Among them, Loops 1 and 3 are the most significant. Loop 1, with the highest unit weight, demonstrates how a lack of respect and trust (C01) triggers weak culture, poor collaboration, and limited training, leading to low motivation and poor decision-making. Loop 3, with the highest centrality weight, highlights how poor leadership, negative attitude, and weak communication reinforce each other. Both loops show that improving trust, leadership, and collaboration is crucial to breaking self-reinforcing behavioural patterns that sustain inefficiencies. Expert interviews confirmed this, noting that leadership commitment and cultural support are essential to overcoming resistance and promoting collaborative lean practices.

Loop 1:

C01 → O02 → O04 → C03 → O05 → T03 → A04 → CM05 → B01 → CM03 → D05 → O03 → D08 → B03 → B08 → B04 → B09 → C07 → C06 → CM01 → B05 → C01

Loop 3:

C01 → CM03 → D05 → O03 → D08 → B03 → B08 → C07 → C06 → CM01 → C03 → O05 → T03 → A01 → A06 → O02 → O04 → B09 → B04 → B05 → C01

6. Conclusion

The efficiency of lean construction scheduling is shaped by a wide range of human factors that extend beyond technical processes. This study found recurring challenges such as skill shortages, an ageing workforce, training issues, low motivation, cultural resistance, and weak collaboration. These issues disrupt workflow reliability, delay project delivery, and limit the expected benefits of lean practices. Their influence is systemic rather than isolated, affecting project performance at multiple stages.

A qualitative design was adopted, using a systematic literature review (SLR) and expert interviews to capture both global evidence and local perspectives. The SLR analysed 77 studies, identifying 615 factors that were refined into 54 categories. Network analysis revealed six factors as most critical: lower motivation and engagement (B05), inadequate collaboration between stakeholders (C03), inadequate commitment and support from top management (O03), cultural resistance to change (O04), conservative and negative attitude (B03), and inadequate conceptual knowledge (A01). Expert interviews confirmed their relevance and highlighted additional themes, including psychological safety and transformational leadership.

These results address the research objectives by identifying the most influential people-centric factors and proposing strategies to mitigate their impact. The study indicates that interventions should target structurally influential factors rather than isolated variables. Centrality analysis suggests that leadership commitment, motivation, collaboration, and lean literacy function as leverage points within the broader relational system. Addressing these high-centrality factors first may generate wider systemic improvement and reduce the risk of fragmented or superficial lean adoption.

6.1 Research originality

This research uniquely combines a systematic literature review with systems thinking and network analysis to explore how human factors collectively influence lean construction scheduling. Unlike previous studies that treat these factors separately, it examines their systemic interconnections using causal loop diagrams and centrality measures. A key innovation is the use of eigenvector centrality to identify the most structurally influential factors within the network. By integrating frequency and relational influence, this study provides a holistic framework for understanding and improving lean practices in New Zealand's construction industry. The study is primarily a systems-oriented synthesis of global literature, supported by contextual expert perspectives.

6.2 Theoretical and practical implications

The contribution of this study lies not in identifying new human factors, but in structuring established factors as an interconnected system and distinguishing between prevalence and structural influence. By applying network centrality analysis, the research advances lean construction knowledge beyond descriptive barrier lists and provides actionable prioritisation for managerial intervention.

The centrality analysis identifies six structurally influential factors that function as leverage points within the relational network. This suggests that leadership commitment, motivation, collaboration, and lean literacy should be prioritised as foundational conditions before tool-based optimisation. Such sequencing shifts lean implementation from a procedural focus to a behavioural systems perspective, reducing the risk of superficial adoption.

This study is grounded in socio-technical systems theory and systems thinking, which conceptualise project performance as emerging from interconnected social and technical elements. By applying network and causal loop analysis, it extends behavioural project management research through empirically mapping systemic human interdependencies in lean construction scheduling.

This study contributes to theory and practice by showing that inefficiencies in lean construction scheduling stem not only from operational issues but also from systemic behavioural interactions. Through thematic, causal loop, and network analyses, it demonstrates how factors such as resistance, disengagement, and fragmentation reinforce inefficiencies. The research links qualitative insights with network theory, offering a framework for analysing human factors within interconnected systems. Practically, six key factors, including low motivation, weak collaboration, poor leadership support, cultural resistance, conservative attitude, and limited knowledge, highlight where targeted interventions should focus to enhance collaboration, leadership, and learning, fostering sustainable lean practices in New Zealand construction.

6.3 Limitations and future research

This study offers valuable insights into the human factors affecting lean construction scheduling in New Zealand, but it has several limitations. The systematic literature review used only peer-reviewed sources, excluding grey literature that could add practical context. Synthesising global findings may have diluted local nuances, and the five expert interviews, though rich in insight, limited the diversity of industry perspectives. While the sample size was limited, future research may expand participant representation to strengthen empirical robustness and broader industry applicability. The study also focused mainly on human-related variables, omitting external influences such as financial pressures or supply chain issues. Future research should expand participation, explore themes such as psychological safety and leadership style, and apply mixed-methods approaches to enhance generalisability and practical relevance.

Future research may examine causal relationships among the identified factors to understand better how these dynamics evolve over time. Further studies could also test the framework's transferability to other project-based industries.

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Supplementary material

The supplementary material for this article can be found online

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