

Restructuring Indian Construction: A Multi-Stakeholder Analysis of Lean Practices and Barriers

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Abstract

India's construction industry has a workforce of more than 50 million and accounts for approximately 8–9% of the country's gross domestic product. Despite this size, it is regularly overwhelmed by time and cost overruns and quality issues. Lean Construction (LC) is strongly promoted as a solution to these problems, but it remains to be implemented in the Indian industry. This gap is filled in the current study through a survey with 225 construction industry professionals from contracting companies, consulting companies, and government departments in India. The tools used to analyse the data were: Relative Importance Index (RII), Spearman's rank correlation, Analysis of variance, Kruskal-Wallis validation and exploratory factor analysis (EFA). The study assesses awareness, frequency of lean use, barriers to lean use, and promotional efforts. The underlying scales were found to be very reliable. The outcome indicated a moderate level of awareness of lean principles and tools. But there is a correlation between awareness and frequency of use. Such a high correlation suggests that the problem of knowledge and use of LC is far more complex in India than traditional institutional theory would suggest. The adoption barriers were categorised into six groups using EFA. Limited technical or financial constraints were a strong contributor to organisational culture and leadership commitment. The overwhelming majority of results indicated that mandatory lean policies and regulations are the most important drivers of adoption, and that better environmental performance is the biggest benefit.

1. Introduction

In India, more than 50 million people work in construction, making it the largest sector after agriculture. It is an extremely large sector that contributes 8%-9% of national GDP, and this trend is observed worldwide, where the construction sector is the major contributor to economic output and jobs (Gohil & Malek, 2023; Sharma & Tiwari, 2023). A combination of low productivity, time and cost overruns and quality defects is consistently destroying client satisfaction and industry competitiveness. Despite the sector's size, they remain pervasive (Oladiran, 2017). Lean construction (LC) has become a key structural solution to address these operational shortcomings. Finally, the International Group for Lean Construction (IGLC) developed a model for lean construction based on Toyota's post-war manufacturing model in Japan. Koskela (1992) brought this paradigm shift to the construction industry. LC is really a full production lifecycle management approach. The predominant framework's main characteristics are directed toward two goals: maximising value to the user and systematically removing non-value-adding waste (Ballard & Howell, 2003; Womack & Jones, 1997). The paradigm is based on five basic principles: Value definition, Value stream mapping, Flow optimisation, Pull-based scheduling and Continuous perfection. Tools for implementing these principles include just-in-time delivery, the Last Planner System, 5S methodologies, total quality management, Kaizen and prefabrication workflows. The efficacy of these tools on the ground has been widely validated with quantifiable improvements in time, cost, and quality, as in Scandinavia (Aziz & Hafez, 2013), Brazil (Ikram et al., 2025), the UK (Nagesh, 2026), and the US.

The lean construction journey in India is unique. Evidence of usage is low and uneven across organisational sectors and geographical areas, and the framework is emerging. Research by Sacks et al.

(2010) and Bajjou and Chafi (2018) shows that lean methods are applicable to project contexts in India. However, the literature has established that it is a viable concept in theory but has not yet captured the reality of how the wider sector understands and utilises the concepts (Shankar et al., 2025). It's a critical industry need, and the risk is extremely high. The Indian construction industry is experiencing a boom, bolstered by substantial investments in infrastructure, urbanisation, and the government's Housing for All initiative. The formalisation and adoption of LC today will have a significant impact on project costs, efficiency, client satisfaction and sustainability outcomes (Aslam et al., 2024; Gohil et al., 2025). The limited scope of research and scale problems have been present in Indian contexts in the past. For instance, Sharma and Tiwari (2023) performed a study based on only 37 respondents/practitioners, Kovvuri et al. (2016) focused on three major companies, while M et al. (2017) demonstrate only a single case study. All of this previous research failed to determine if there are patterns of lean awareness or barriers to lean adoption in the Indian construction industry. Most importantly, previous studies have ignored two key questions: Is there a statistical correlation between knowledge of lean principles and their use? But what are the 'enablers' that those in the public and private sectors prefer, and how do they differ?

How familiar are Indian practitioners with lean principles, and how often do they employ them? (2) What is the nature of their lean awareness? What is the nature of Indian practitioners' awareness of lean? (3) In what ways do they apply lean principles in practice? (4) What are the reasons for the low levels of lean usage by Indian practitioners? (3) Do the results suggest a significant correlation between awareness and use? (3) What are the main barriers to adoption, and do they group into a distinct underlying structure? (4) What incentives and approaches are key to achieving adoption, and do these differ systematically across the government, contracting and consulting organisations? This study differs from previous studies in that a sufficient number of respondents was used to enable inferential statistics across organisational types. This study uses the Relative Importance Index (RII), Spearman's rank correlation, exploratory factor analysis, and one-way ANOVA (verified by the Kruskal-Wallis test). This is the first cross-organisational Indian LC maturity evaluation based on statistical data. After this introduction, Section 2 reviews the literature on productivity, lean theory, and barriers to lean adoption. The methodology and statistical tools that are used are defined in Section 3. Our findings, analysis, final recommendations, and limitations are described and analysed in Sections 4, 5, and 6.

2. Literature Review

2.1 The Construction Industry and Its Challenges

Construction is among the least productive of the world's largest industries, despite its size and economic importance. Tezel et al. (2017) report that productivity in the sector has remained constant or declined relative to manufacturing over the last 50 years. Enshassi et al. (2007) report that the productivity gap is worse in developing economies where supply chains are fragmented, and there is a shortage of trained and formalised workers. India is no exception: Gohil and Malek (2023) identify insufficient preconstruction planning and weak contractor capabilities as specific constraints burdening

the Indian sector. Koskela (1992) adapted Taiichi Ohno's construction waste classification and found that these structural deficiencies correlate well with the categories of waste. The magnitude of the issue has been illustrated by cross-national studies by Ramaru (2020) and Bajjou and Chafi (2018), which indicated that up to 10% to 30% of the project costs are spent on material waste, which makes it evident that the focus of lean construction is not to work faster, but to eliminate waste.

2.2 Overview of Lean Construction

Lean thinking began in manufacturing with the Toyota Production System, developed by Taiichi Ohno and Shigeo Shingo at Toyota in the 1950s, which used Just-In-Time (JIT) production and Jidoka. These were first popularised in the West by Womack *et al.* (1990) in *The Machine That Changed the World* and then later in the lean framework of five steps across industries by Womack and Jones (1997). The first adaptation towards construction occurred with Koskela's (1992) suggestion of the Transformation-Flow-Value (TFV) model, which challenged the conversion-based thinking of construction management. The International Group for Lean Construction was founded the following year (Ballard & Tommelein, 2012), and Ballard and Howell began developing the Last Planner System in 1994 – built around the Percent Plan Complete (PPC) metric for schedule reliability – finalising the system in 2003 (Power *et al.*, 2021; Salazar *et al.*, 2018). Since its formation in 1997, the Lean Construction Institute has been championing research and practice in the field. (Salem *et al.*, 2005).

2.3 Lean Principles and Techniques

A recurring distinction in the literature separates lean *principles* – the underlying logic of value. A recurring difference in the literature is between lean principles and value stream; the former is the logic behind the value stream. Lean tools – the specific processes for eliminating waste – and waste elimination – the logic for eliminating waste (Salem *et al.*, 2005). This study is based on five principles that are well summarised by Womack and Jones (1997): connect value definition to customers' perspective; trace the value stream to identify waste; sustain value stream schedules; pull work through, not push; and strive for perfection through continuous improvement. The toolkit that goes along with it is divided into two families: quality- Production-management tools like Lean, and management tools like TQM, Kaizen, and Poka-Yoke. Studies of implementation have shown that just-in-time delivery, Kanban and the Last Planner System all support a review. It is the disciplined application of these tools, not just the use of the word "lean," that drives Evident's project progress towards measurable improvements.

2.4 Barriers to Lean Adoption

Despite strong arguments for the benefits of lean construction, it hasn't been widely adopted. Beyond the theory, there is also partial adoption in developed economies, such as the USA (Aslam *et al.*, 2024; Suseelan *et al.*, 2025). Six general categories of barriers are found in the literature: culture, management, technology, finance, and regulation (Gohil *et al.*, 2025; Gohil & Malek, 2023; Pipaliya & Malek, 2025). These categories are demonstrated through country-specific studies. Vary across institutions. According to Ramaru (2020), one of the factors that give rise to the problem is the lack of understanding of lean practices and the lack of executive support, which are among the most important challenges in South

Africa, according to Oladiran (2017), there was resistance to organisational change in Nigeria, while Bajjou and Chafi (2018) highlight fragmentation within Morocco's supply chains; Nesensohn et al. (2014) discover deeply rooted organisational fragmentation. The major challenges in the United Kingdom are culture and, according to Kovvuri et al. (2016), weak government. Water availability is the limiting factor in India. Wu et al. (2022), in a cross-country bibliometric study, add government agencies to this picture—they have lower rates of consistency. The fact that consultants and contractors have lean maturity is tested directly in this study, and it is found that these firms are leaner than those in India. context.

2.5 Measures for Enhancing Lean Adoption

There is also a parallel literature that explores how to make lean adoption quicker (Demirkesen et al., 2019; Ikram et al., 2025; Tezel et al., 2017; Van Assen, 2018). There are three types of recurring interventions. The first, Monyane et al. (2020) suggest, is the need to reach a critical mass of practitioners trained in lean principles and tools, which encourages formal lean teaching in the engineering and construction management curriculum. Second, Sacks et al. (2010) conclude that change efforts will not succeed without ongoing support from top management, thereby making top-management commitment another lever. Third, the experience of the United Kingdom with industry-wide mandates for lean in public procurement (Egan, 1998; Latham, 1994) shows that policy-driven mandates can replace or accelerate industry-wide uptake of organics in situations where it is not occurring. The adoption-measures scale in this study is conceptually grounded in the three levers of training, leadership commitment and regulation.

2.6 Benefits of Lean Construction

The case for the value of lean construction is well established in many countries worldwide. Positive results have been reported in all the comparative case studies, including from the United States (Ballard & Howell, 2003), Brazil (Formoso et al., 2002), the United Kingdom (Howell, 1999), and Scandinavia (Sacks et al., 2010), in terms of schedule, cost, quality and safety. According to the meta-analysis by Mossman (2009), these benefits can be measured at the project level: Cost savings of 10%-15% and a 15%-25% reduction in project duration. In addition to these project-level indicators, the literature also reports organisational-level benefits, such as increased customer satisfaction, that occur when lean practices are not just a single event but have become embedded.

2.7 Lean Construction in India

Considering the robust evidence around the globe, the number of studies focused on lean construction in the Indian context is small, and the studies that do exist are, unfortunately, on a small scale. Sharma and Tiwari (2023) investigated industry sentiment, surveyed 37 participants, and found only a moderate level of awareness, with lean construction principles implemented to a lesser degree. Sharma and Tiwari (2023) indicated that these findings were due to the lack of legislative frameworks and the strong presence of legacy project management systems. Kovvuri et al. (2016), studying three large Indian construction firms, found that senior leaders recognised the value of lean construction in principle, but that adoption stalled at the middle and frontline levels due to insufficient training and cultural resistance.

M *et al.* (2017) applied the Last Planner System to a single residential project and achieved a 20% improvement in schedule reliability, but reported that the approach could not be readily scaled to other projects or organisations. Each of these studies establishes that lean construction can work in India, or that awareness is currently limited — but none has the sample size or organisational range to determine how these patterns vary across the public and private actors who together deliver the bulk of Indian construction output, or whether the gap between awareness and application is large or small once measured systematically. This is the gap the present study is designed to close.

3. Research Methodology

3.1 Research Design and Approach

This study adopts a quantitative cross-sectional survey design, an approach well suited to mapping the distribution of practitioners' perceptions, attitudes, and practices at a single point in time (Creswell, 2014). The questionnaire adapts validated measurement instruments developed by Malek and Bhatt (2023) and Malek and Gundaliya (2020b) to the Indian construction context. The adapted instrument was reviewed by five academic and industry experts prior to deployment to confirm content validity and contextual relevance.

3.2 Questionnaire Design

The questionnaire comprises five sections (Malek & Bhatt, 2022). Section A collects demographic and occupational information, including educational attainment, years of professional experience, and organisation type. Section B uses a five-point Likert scale to measure respondents' awareness and frequency of use of five lean principles and 22 lean tools. Sections C through E each use a five-point agreement scale to measure, respectively, 20 barriers to adoption, 14 adoption-promoting measures, and 18 perceived benefits.

3.3 Target Population and Sampling

The target population was practising construction professionals directly involved in project delivery in India (Malek & Shah, 2023). The sample spans six professional roles — including civil engineers and architects — drawn from three organisation types: government agencies, contracting companies, and consulting firms. Purposive stratified sampling was used to ensure representativeness across these groups (Malek & Gundaliya, 2020). Distribution combined offline collection at construction sites and offices with online distribution via Google Forms, the Indian Institution of Engineers, and the Construction Industry Development Council. Of 261 questionnaires issued, 225 valid responses were retained after data cleaning, yielding a valid response rate of 86.2%, well above the 60% threshold that Fellows and Liu (2015) identify as adequate for this research field (Malek *et al.*, 2021; Malek & Gundaliya, 2020; Malek & Zala, 2021).

3.4 Data Analysis Methods

The analysis was carried out in five phases. The demographic profile of the sample was obtained using frequency distributions. Second, the weight assigned to each response option was added together to determine the Relative Importance Index (RII) for each survey item, using the formula $RII = \sum W / (A \times N)$, where W is the weight assigned to each response option, A is the maximum weight on the five-point scale, and N is the number of respondents, with higher RII values indicating greater perceived importance of the item and RII values ranged from 0 to 1, that the greater the value the more important the item, thus the items would be ranked (Abdulmaksoud et al., 2025; Al-Hamadani et al., 2021). Third, Cronbach's alpha was used to determine the internal consistency of the multi-item scales, and Spearman's Rank correlation was used to directly test the hypothesis of a relationship between the application frequency of lean principles and tools and their awareness, for each pair of scores. (Malek et al., 2021). The Least Significant Difference (LSD) post-hoc tests were used for one-way ANOVA to compare mean differences among the three types of organisation (Malek & Zala, 2021) (government (GOV), contractors (CON) and consultancy/academic organisations (ORG)) and Kruskal-Wallis H-tests were conducted to assess the robustness of these comparisons in a non-parametric manner. Fifth, exploratory factor analysis (EFA) was performed separately on the barriers scale, adoption measures scale, and benefits scale (Malek & Bhatt, 2023). To assess sampling adequacy, the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity were performed before principal component analysis with Varimax rotation, and only factors with an eigenvalue greater than 1 were retained (Malek & Bhatt, 2022; Upadhyaya et al., 2026).

4. Results

4.1 Demographic Profile of Respondents

Table 1 presents the demographic characteristics of the 225 valid respondents, including education, occupation, years of professional experience, and organisational affiliation. The sample is highly educated, with 46.0% of respondents possessing a bachelor's degree, 21.1% a master's degree and 11.5% a doctorate, reflecting their ability to make informed judgements about lean concepts. The spread across professional roles and organisation types gives the sample the breadth needed to support the cross-organisational comparisons reported in Section 4.6.

Table 1
Demographic Profile of Respondents

Category	Subcategory	Frequency	Valid %	Cumulative %
Education	Diploma	20	7.7	7.7
	Bachelor's Degree	120	46.0	53.7
	Master's Degree	55	21.1	74.8
	Doctorate	30	11.5	86.3
	Missing	36	13.8	100.0
Profession	Architect	5	2.0	2.0
	Civil Engineer	165	66.0	68.0
	Structural Engineer	15	6.0	74.0
	Project Manager	30	12.0	86.0
	Planning Engineer	10	4.0	90.0
	Missing	25	10.0	100.0
Experience	< 5 years	155	68.9	68.9
	6–10 years	30	13.3	82.2
	11–15 years	10	4.4	86.7
	> 20 years	30	13.3	100.0
	Missing	36	—	—
Organisation	Government	25	11.1	11.1
	Contractor/Consultant	125	55.6	66.7
	Consultancy (Academic/Private)	75	33.3	100.0
	Missing	36	—	—

4.2 Reliability Analysis

Table 2 reports Cronbach's alpha for the seven measurement scales. All exceed 0.87, with the lean-principle-awareness scale the lowest at 0.873 and the benefits scale the highest at 0.967, comfortably clearing the reliability thresholds established by Malek and Bhatt (2022, 2023) and Upadhyaya et al. (2026) for this research area. These results justify the use of composite RII scores for the substantive analysis that follows.

Table 2
Reliability Analysis – Cronbach's Alpha Coefficients

Construct / Section	No. Items	N (valid)	Cronbach's α	Interpretation
Lean Principles Awareness	5	225	0.873	Good
Lean Techniques Awareness	17	225	0.933	Excellent
Lean Principles Frequency	5	225	0.891	Good
Lean Techniques Frequency	16	225	0.934	Excellent
Barriers to Lean Adoption	20	225	0.956	Excellent
Measures for Lean Adoption	14	225	0.951	Excellent
Benefits of Lean Adoption	18	225	0.967	Excellent

4.3 Level of Awareness of Lean Principles and Techniques

Table 3 ranks the 22 lean-related survey items by RII. The overall average RII is 0.635, placing practitioner awareness at a “slightly familiar” level rather than the “moderately” or “highly” familiar levels the industry would need to support widespread adoption. Among the five principles, “pursuit of perfection” is best known (MIS = 3.533, RII = 0.706), while value stream mapping is least known. Among the 17 techniques, first-article inspection and just-in-time delivery rank highest, while the more analytically demanding quality tools – the 5 Whys method and the Ishikawa diagram – share the lowest RII of 0.546. Indeed, nothing higher than rank 8 is at the $RII \geq 0.7$ level of “moderately familiar” and thus only two-thirds of the items surveyed are at the level of awareness that the literature considers meaningful for adoption. This pattern shows that Indian practitioners' knowledge is shallow and wide - well-known names, less depth.

Table 3
Relative Importance Index – Awareness of Lean Principles and Techniques

Rank	Item	MIS	RII	Level
1	Pursuing perfection (Principle)	3.533	0.706	Moderately Aware
2	Identifying value (Principle)	3.244	0.648	Somewhat Aware
3	Achieving flow in the process (Principle)	3.178	0.636	Somewhat Aware
4	Customer (client) pulls (Principle)	3.111	0.622	Somewhat Aware
5	Value stream mapping (Principle)	3.022	0.604	Somewhat Aware
6	First-run studies (Technique)	3.533	0.706	Moderately Aware
7	Just-in-time / JIT (Technique)	3.422	0.684	Moderately Aware
8	Standardisation (Technique)	3.422	0.684	Moderately Aware
9	Prefabrication (Technique)	3.400	0.680	Moderately Aware
10	Kaizen – continuous improvement (Technique)	3.333	0.666	Somewhat Aware
11	Total quality management – TQM (Technique)	3.311	0.662	Somewhat Aware
12	Last Planner System – LPS (Technique)	3.244	0.648	Somewhat Aware
13	5S process (Technique)	3.200	0.640	Somewhat Aware
14	Visual management (Technique)	3.178	0.636	Somewhat Aware
15	Waste elimination / Muda (Technique)	3.111	0.622	Somewhat Aware
16	Value stream mapping (Technique)	3.044	0.608	Somewhat Aware
17	Pareto analysis (Technique)	2.978	0.596	Slightly Aware
18	Error proofing / Poka-Yoke (Technique)	2.911	0.582	Slightly Aware
19	Kanban/pull system (Technique)	2.844	0.568	Slightly Aware
20	FMECA (Technique)	2.822	0.564	Slightly Aware
21	Ishikawa / Fishbone diagram (Technique)	2.733	0.546	Slightly Aware
22	Five Whys (Technique)	2.733	0.546	Slightly Aware

4.4 Frequency of Application of Lean Principles and Techniques

The scores for application frequency RII are reported in Table 4, and the average is 0.636, which is very close to the average for awareness reported in Section 4.3. This near-equality is informative in itself, as it indicates that, overall, Indian practitioners apply lean tools more or less in accordance with their

understanding of the tool, rather than over- or underusing them based on their claimed knowledge. Again, "pursuit of perfection" is most frequently applied, followed by "first run studies" and "standardisation" as these are also the lowest ranked in terms of awareness, and then come "Kanban", "Ishikawa diagrams", and "FMECA. The difference between awareness and application RII is near zero or slightly negative for most items, suggesting practitioners apply these tools slightly more often than they report awareness, which is consistent with the idea that tacit learning (on-the-job) takes place before formal conceptual learning. Prefabrication is the obvious exception, where the gap between practitioners' awareness and their use is positive (+ 0.20): this is easiest to explain as being due to cost and logistical considerations, rather than a lack of conceptual understanding.

Table 4
Relative Importance Index – Frequency of Application of Lean Principles and Techniques

Rank	Item	MIS	RII	Frequency Level
1	Pursuing perfection (Principle)	3.667	0.734	Almost every time
2	Achieving flow in the process (Principle)	3.378	0.676	Sometimes
3	Identifying value (Principle)	3.311	0.662	Sometimes
4	Customer pull (Principle)	3.311	0.662	Sometimes
5	Value stream mapping (Principle)	3.156	0.632	Sometimes
6	First-run studies (Technique)	3.444	0.688	Sometimes
7	Standardisation (Technique)	3.422	0.684	Sometimes
8	Just-in-time / JIT (Technique)	3.356	0.672	Sometimes
9	Kaizen (Technique)	3.289	0.658	Sometimes
10	TQM (Technique)	3.267	0.654	Sometimes
11	Visual management (Technique)	3.244	0.648	Sometimes
12	Last Planner System (Technique)	3.222	0.644	Sometimes
13	Prefabrication (Technique)	3.200	0.640	Sometimes
14	5S process (Technique)	3.200	0.640	Sometimes
15	Value stream mapping (Technique)	3.178	0.636	Sometimes
16	Waste elimination (Technique)	3.111	0.622	Sometimes
17	Error proofing / Poka-Yoke (Technique)	3.022	0.604	Sometimes
18	Pareto analysis (Technique)	2.956	0.592	Slightly
19	FMECA (Technique)	2.889	0.578	Slightly
20	Kanban (Technique)	2.867	0.574	Slightly
21	Ishikawa diagram (Technique)	2.844	0.568	Slightly

4.5 Spearman Rank Correlation: Awareness versus Frequency of Application

The Spearman correlation between awareness scores and application frequency was reported in Table 5. There is a strong and highly significant correlation for lean techniques ($\rho = 0.944$, $p < 0.001$), that is, tools that practitioners know more about are used more. Very little doubt on lean techniques, where the correlation is strong and highly significant ($\rho = 0.944$, $p < 0.001$). However, for lean principles, it is not that the relationship is weaker; it is just a function of statistical power, and the correlation is just shy of

conventional significance ($\rho = 0.821$, $p = 0.089$). If all 21 items are pooled, the artefact is collapsed, and the resulting $\rho = 0.868$ ($p < 0.001$) indicates a strong statistical association between awareness and application across all items. In practice, raising awareness of certain lean tools and principles should be expected to lead to increased use of those tools and principles, not to the increase in awareness, followed by the increase in use, which are often assumed to take place in the literature, but are in fact separated by structural or institutional barriers.

Table 5
Spearman Rank Correlation — Awareness vs. Frequency of Application

Comparison	Spearman ρ	p-value	Significance
Principles: Awareness vs Frequency of Application	0.821	0.089	Marginal ($p < 0.10$)
Techniques: Awareness vs Frequency of Application	0.944	< 0.001	Highly Significant ***
All Items Combined: Awareness vs Frequency	0.868	< 0.001	Highly Significant ***

4.6 Organisation-type Differences: ANOVA and Kruskal-Wallis Results

Table 6 reports selected results from one-way ANOVA (with LSD post-hoc tests) and Kruskal-Wallis H-tests comparing government agencies (GOV), contractors (CON), and consulting/academic organisations (ORG). The pattern is consistent across awareness and application: of 22 lean awareness indicators, 19 differ significantly between GOV and CON ($p < 0.05$ or better), and all five lean-principle application-frequency items show significant inter-group differences. ORG outperforms CON in only two application dimensions — prefabrication and pursuit of perfection — suggesting that consulting and academic organisations' relative strength is concentrated in higher-order practices rather than across the board. The barriers data break this pattern. Rather than GOV trailing CON and ORG as it does on awareness and application, perceptions of barriers diverge in a less linear, more organisation-specific way: GOV respondents rate top-management commitment and lack of awareness as more severe barriers than CON does, while CON rates poor stakeholder communication more severely than either GOV or ORG. This divergence matters because it implies that a single, generic barrier-reduction strategy is unlikely to work equally well across organisation types — an issue taken up further in Section 5.2.

Table 6
Selected ANOVA Results by Organisation Type (GOV = Government; CON = Contractor; ORG = Consultancy)

Variable / Item	GOV Mean	CON Mean	ORG Mean	F-stat	p-value	Sig.
Identifying value (Awareness)	2.60	3.52	3.00	7.167	< 0.001	***
Achieving flow in the process (Awareness)	2.60	3.36	3.07	6.789	0.001	**
Customer pull (Awareness)	2.40	3.04	3.47	9.735	< 0.001	***
Pursuing perfection (Awareness)	2.60	3.72	3.53	13.193	< 0.001	***
Prefabrication (Awareness)	2.20	3.64	3.40	15.941	< 0.001	***
First-run studies (Awareness)	2.60	3.88	3.27	18.422	< 0.001	***
Pursuing perfection (Frequency)	2.60	3.64	4.07	16.099	< 0.001	***
Prefabrication (Frequency)	2.60	2.92	3.87	20.386	< 0.001	***
Lack of awareness (Barrier)	3.40	3.40	2.60	19.304	< 0.001	***
Top mgmt. commitment (Barrier)	3.80	3.76	2.80	21.733	< 0.001	***
Poor communication (Barrier)	3.00	3.80	2.93	17.531	< 0.001	***
Improves safety (Benefit)	3.80	4.00	3.20	17.116	< 0.001	***
Improves env. performance (Benefit)	3.80	4.20	3.73	6.668	0.002	**
Decreases defects (Benefit)	4.40	3.56	3.67	6.217	0.002	**
<i>Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$. F statistics and means based on N = 225 (GOV = 25; CON = 125; ORG = 75).</i>						

4.7 Barriers to Lean Adoption

Table 7 lists all 20 barriers in order of RII. There was low overall agreement, with an average RII of 0.669, suggesting that the listed barriers do hinder adoption. Lack of organisational culture (0.728), lack of top-management commitment (0.688), absence of a lean culture (0.688) and poor stakeholder communication (0.684) are the barriers most strongly endorsed; poor stakeholder communication

(0.622) is the least endorsed. The overall trend across the ranking is that cultural and managerial barriers consistently outrank technological barriers, indicating that the lean adoption challenge for India is fundamentally an organisational behaviour challenge rather than a resource/capability gap. For this reason, policy and managerial focus need to shift. (see Section 5.3).

Table 7
Relative Importance Index – Barriers to Lean Adoption

Rank	Barrier	MIS	RII	Level of Agreement
1	Lack of organisational culture (LCBR16)	3.644	0.728	Agree
2	Lack of top management commitment (LCBR6)	3.444	0.688	Agree
3	Absence of lean culture (LCBR13)	3.444	0.688	Agree
4	Poor communication among stakeholders (LCBR9)	3.422	0.684	Agree
5	Lack of government support (LCBR20)	3.400	0.680	Agree
6	Human resistance to change (LCBR15)	3.400	0.680	Agree
7	Lack of time for innovation (LCBR3)	3.400	0.680	Agree
8	Uncertainty in supply chain (LCBR12)	3.378	0.676	Agree
9	Inadequate pre-planning (LCBR14)	3.356	0.672	Agree
10	High cost of lean training (LCBR17)	3.356	0.672	Agree
11	Lack of lean specialists (LCBR18)	3.356	0.672	Agree
12	Inaccurate and incomplete designs (LCBR5)	3.356	0.672	Agree
13	Lack of lean training (LCBR7)	3.333	0.666	Agree
14	Poor standardised procurement strategies (LCBR4)	3.311	0.662	Agree
15	Lack of lean understanding (LCBR1)	3.267	0.654	Neutral–Agree
16	Lack of implementation methodology (LCBR10)	3.244	0.648	Neutral–Agree
17	Insufficient financial resources (LCBR19)	3.244	0.648	Neutral–Agree
18	Lack of client interest (LCBR8)	3.178	0.636	Neutral
19	Lack of adequate lean awareness (LCBR2)	3.133	0.626	Neutral
20	Lack of prefabrication techniques (LCBR11)	3.111	0.622	Neutral

4.8 Factor Structure of Barriers

To determine if there are fewer coherent underlying dimensions in the 20 barriers, exploratory factor analysis was performed. The sampling was adequate ($KMO = 0.699$, $p > 0.6$), and Bartlett's test of sphericity was significant ($\chi^2 = 3605.113$, $df = 190$, $p < 0.001$), allowing factor extraction. Six factors with

eigenvalues greater than 1 were selected, accounting for 78.9% of the total variance, and factors with loadings greater than 0.4 were interpreted and named. The complete structure is in Table 8.

Table 8
Factor Structure of Barriers to Lean Adoption (EFA, PCA with Varimax Rotation)

Factor	Key Items	Var. Explained
F1: Awareness & Knowledge Deficiency	Lack of lean understanding, awareness, government support, and financial resources	17.3%
F2: Procedural & Standardisation Barriers	High cost of training, lack of specialists, prefabrication, and supply chain	15.4%
F3: Structural & Organisational Barriers	Lack of time, poor procurement, lack of training, and no implementation methodology	14.6%
F4: Stakeholder & Cultural Barriers	Inaccurate designs, absence of lean culture, lack of management commitment	11.1%
F5: Communication & Management Barriers	Poor communication, lack of client interest, and top management issues	10.6%
F6: Financial & Planning Barriers	Inadequate pre-planning, human resistance to change	9.9%
Total		78.9%

Ranked by variance explained, Factor 1 (Awareness and Knowledge Deficiency, 17.3%) groups insufficient understanding of lean principles with funding shortages, suggesting that knowledge gaps and resource gaps are perceived as intertwined rather than separate problems. Factor 2 (Procedural and Standardisation Barriers, 15.4%) comprises the cost of training, the lack of specialists, prefabrication, and supply-chain issues, which is the group associated with the practical infrastructure required to implement lean. Factor 3 (Structural and Organisational Barriers, 14.6%) includes time pressure, procurement weaknesses, inadequate training, and a lack of implementation methodology, suggesting a lack of organisational readiness rather than a lack of individual skills. Factor 4 (Stakeholder and Cultural Barriers, 11.1%) is linked to design inaccuracies due to a lack of a lean culture, while Factor 5 (Communication and Management Barriers, 10.6%) groups poor communication among stakeholders, low client interest, and management issues. Financial and Planning Barriers (9.9%) is the smallest factor, a combination of a lack of pre-planning and opposition to change. Two patterns emerge. First, “lack of awareness” (Factor 1) and “absence of lean culture” (Factor 4) are statistically independent constructs, but these factors are commonly discussed together in a policy context as a single “knowledge problem”, which suggests that campaigns to build awareness will not fix the cultural resistance that is represented in Factor 4. Second, financial constraints are not necessarily an overriding factor; they are embedded in procedural (F2) and planning (F6) factors, suggesting that financial constraints are felt by the respondents less as a barrier than as a result of poor planning and weak technical infrastructure.

4.9 Measures for Improving Lean Adoption

The 14 adoption measures are ranked in Table 9, and the overall mean score is 0.741, indicating high overall endorsement. The mandatory lean policies and regulations are overwhelmingly the most important, followed by efficient communication systems (MIS = 0.800), employee training and development (MIS = 0.756), proper waste management (MIS = 0.752), and availability of required technology (MIS = 0.752). The difference between the top-ranked measure and the others, with the latter being rated “agree”, and the former rated “strongly agree”, indicates that respondents consider the measure to be qualitatively more important as a lever on regulation than the others, not just the most favoured among the other measures ranked as “agree”.

Table 9
Relative Importance Index – Measures for Improving Lean Adoption

Rank	Measure	MIS	RII	Level of Agreement
1	Mandatory lean policies and regulations (LCAD8)	4.000	0.800	Strongly Agree
2	Efficient communication system (LCAD6)	3.889	0.778	Agree
3	Employee training and development (LCAD3)	3.778	0.756	Agree
4	Proper waste management (LCAD11)	3.756	0.752	Agree
5	Availability of required technology (LCAD14)	3.756	0.752	Agree
6	Collaboration among stakeholders (LCAD10)	3.733	0.746	Agree
7	Top management commitment (LCAD5)	3.711	0.742	Agree
8	Client support (LCAD12)	3.689	0.738	Agree
9	Proper site management (LCAD13)	3.689	0.738	Agree
10	Government support (LCAD7)	3.667	0.734	Agree
11	Lean education in higher institutes (LCAD2)	3.600	0.720	Agree
12	Lean awareness (LCAD1)	3.578	0.716	Agree
13	Availability of lean experts (LCAD4)	3.511	0.702	Agree
14	Favourable lean organisational culture (LCAD9)	3.489	0.698	Agree

According to the factor analysis, the sampling adequacy is KMO = 0.721, Bartlett's $p < 0.001$, and the four factors account for 74.1% of the total variance. Factor 1 (Education and Training, 21.8%) includes lean awareness, lean education, employee development, lean experts, and top management commitment, a very wide range of concepts that makes it seem as though top management commitment is part of the same set of constructs as training and capability-building, and not a governance matter. Factor 2 (Client and Site Management, 20.9%) groups together client support, site management and availability of technology. Factor 3 (Governance and Communication, 19.0%) refers to communication systems, government support, mandatory policy, and organisational culture. Communication is conceptually

included with governance, but not as a separate lever, which is interesting, as mandatory policy is the most highly rated in Table 9. Factor 4 (Waste and Collaboration, 12.4%) combines stakeholder collaboration with waste management practices.

4.10 Benefits of Lean Adoption

Table 10 shows the ranking of the 18 perceived benefits of lean adoption by RII. Overall, the average RII among respondents was 0.750, indicating that they perceive real value in lean practices. The improvement in environmental performance is noted as the top priority (RII = 0.800, “strongly agree”), which aligns with the environmental performance focus in green building certification schemes of India and also within the Smart Cities Mission, followed by reduction in defect, reduction in waste, reduction in project duration and efficient usage of equipment. There is only one benefit for which there is less than a clear consensus: the reduced project cost (RII = 0.684), which ranks at the bottom of the list. The findings were unexpected as cost reduction is the benefit most often cited in the international lean literature (Mossman, 2009), and Indian practitioners find this benefit more tangible and immediate than the financial benefit, which might emerge more slowly, allowing for the myriad elements that influence project cost to become apparent.

Table 10
Relative Importance Index – Benefits of Lean Adoption

Rank	Benefit	MIS	RII	Level of Agreement
1	Improves environmental performance (LCBT2)	4.000	0.800	Strongly Agree
2	Decreases defects (LCBT16)	3.911	0.782	Agree
3	Reduces waste (LCBT3)	3.889	0.778	Agree
4	Reduces project duration (LCBT4)	3.844	0.768	Agree
5	Efficient equipment use (LCBT10)	3.822	0.764	Agree
6	Improves effective communication (LCBT17)	3.800	0.760	Agree
7	Encourages collaboration (LCBT18)	3.800	0.760	Agree
8	Meets client needs (LCBT7)	3.756	0.752	Agree
9	Increases productivity (LCBT5)	3.756	0.752	Agree
10	Improves safety (LCBT1)	3.711	0.742	Agree
11	Minimises double handling (LCBT6)	3.711	0.742	Agree
12	Improves target costing (LCBT8)	3.711	0.742	Agree
13	Improves quality (LCBT12)	3.689	0.738	Agree
14	Encourages relevant equipment use (LCBT11)	3.689	0.738	Agree
15	Reduces inventory (LCBT13)	3.689	0.738	Agree
16	Decreases accident chances (LCBT9)	3.667	0.734	Agree
17	Maximises multi-skilled employees (LCBT14)	3.667	0.734	Agree
18	Reduces project cost (LCBT15)	3.422	0.684	Agree

The benefit scale also satisfied both good fit tests ($KMO = 0.826$, Bartlett's $p < 0.001$). Four factors described 74.5% of the total variance. The first (Productivity and Efficiency, 30.1%) accounted for the majority of the variance and had eight of the scale's 18 items (productivity, double handling, efficiency, reduction of waste, reduction of inventory and costs, communication and collaboration). Most of the respondents viewed the gains made from the application of lean construction as an undifferentiated gain, rather than as distinct benefits. The second factor (Safety and Environmental Performance, 18.5%) included safety, environmental performance, project duration, and client satisfaction. The third factor (Quality and Cost Control, 13.3%) was made up of target costing, equipment efficiency, and reduction of defects, while the fourth factor (Workforce and Delivery, 12.6%) included the benefits of a multi-skilled workforce, as well as the benefits of the management of inventory and equipment.

5. Discussion

5.1 Awareness and Application: A Coupled, Not Decoupled, State

The headline awareness finding with an RII average of 0.635, significantly under the 0.80 mark for “high awareness” is in line with earlier studies in South Africa (Ramaru, 2020) and Nigeria (Oladiran, 2017) and indicates that the moderate lean maturity found in the construction sectors of the sub-Saharan African region and South Asia is not an India-specific phenomenon (Aslam et al., 2024). Regarding this number, a simplistic interpretation would indicate no advancement. What is more important is the context of the number: awareness of the different tools is highly inconsistent, with considerable advancement of certain manufactured tools being derived from mature manufacturing such as the tools of just-in-time and standardisation, as compared to the more specialised analytical tools like the Ishikawa diagram and FMECA (Sreram & Thomas, 2023). This is likely a result of the flow from the manufacturing sector in India, where these tools are prevalent, and not an outcome of lean-construction-based training. This is an important distinction for policy, as it indicates that current levels of awareness may be somewhat optimistic when estimating the gains from initiatives in the construction sector compared with other sectors.

The strength of the association between awareness and application ($p = 0.868$, $p < 0.001$, aggregated across all 21 items) is the study's main empirical contribution. This finding contradicts a prevalent assumption in the implementation literature. This assumption is that the persistence of low lean maturity is due to institutional or structural obstacles that prevent practitioners from acting on the knowledge they possess. If this assumption were correct, awareness and application would be weakly linked. Practitioners would be aware of lean tools but be constrained from using them due to procurement, client and organisational obstacles. The evidence suggests otherwise. High awareness is associated with high application, with no evidence of a “knowing-doing gap”, which institutional theory would predict. This should not be taken to mean that institutional obstacles are not present (as shown in Section 5.3, they are), but rather that for specific tools and principles, the presence of barriers is relatively informal and therefore, in line with classical innovation-diffusion theory, increasing awareness would be a direct and informal means of increasing application. This would be a more realistic approach than waiting for institutional changes that create the conditions for application. The marginal result for the principles subset ($p = 0.821$, $p = 0.089$) is in line with this conclusion. The lack of more than five paired observations limits the statistical strength, and the pooled result clarifies the issue beyond any reasonable doubt.

5.2 Organisation-type Disparities and Their Implications

As presented in Table 6, the gap between government agencies and private contractors is structural, not merely a matter of degree (Tauheed, 2025). General Financial Rules and CPWD codes are guidelines for government construction agencies in India that emphasise compliance and audit traceability. These

frameworks do not have a focus on iterative advances. A lack of tolerance for what hasn't been tried and isn't always true, continuous adjustment, and flexibility are at the heart of lean construction. These lean concepts are at odds with compliance approaches (Gohil et al., 2025). On the other hand, private contractors are directly challenged by the market to be more efficient, and therefore are much more likely to adopt lean practices, particularly from their international clients, reducing the practical obstacles to developing the concept of lean construction. (Maru et al., 2024). This is a different apprehension from the “lack of awareness” so prevalent in the barriers literature. Government respondents are no less informed; rather, they operate within a different regulatory framework in which lean construction principles are neither incentivised nor permitted (Table 6).

This provides a much more practical distinction beyond the construction of a “make employees aware” policy. For training programs in particular, narrowing the GOV-CON-ORG gap is unrealistic, as the main constraint for government agencies is not a lack of awareness but a lack of adherence to procedures. Aligning with the approach taken in the UK's 2020 Construction Playbook, which embeds collaborative and lean-compatible requirements directly into public procurement rules, reforming India's GFR and CPWD frameworks to incorporate lean performance indicators would directly address the structural barrier. Given that government-controlled projects account for the majority of India's infrastructure spending, this is also the segment where a procedural fix would have the largest absolute impact on national lean maturity, even though it is organisationally the hardest segment to reform.

5.3 Barriers: Culture and Leadership, Not Technology or Money

The barriers data converge on a single, consistent message across three independent analytical approaches — RII ranking, ANOVA, and exploratory factor analysis — that lack of organisational culture (RII = 0.728) and lack of top-management commitment (RII = 0.688) outrank every technical or financial barrier in the dataset. This corroborates international evidence that the core constraints on lean adoption sit at the behavioural and institutional level rather than the technical or financial level (Jadhav et al., 2014; Sharma et al., 2024), and is consistent with Liker's (2004) argument that the Toyota model is fundamentally a cultural transformation: organisations that adopt lean tools without internalising lean values tend to see the tools fail. India's usually hierarchical, top-down structures make their findings more consequential: if top management is committed, it becomes a necessary support; if they are not committed, it becomes a barrier. Staff working within a hierarchical structure have little power to effect change. In these cases, senior management commitment is crucial (Moktadir et al., 2018).

The six-factor structure this study develops through EFA is more refined than the three-factor structure reported by Ramaru (2020) for South Africa or the four-factor structure reported by Bajjou and Chafi (2018) for Morocco. It is not just that India faces more barriers. These two frameworks show that the barriers of “awareness deficiency” (Factor 1) and “absence of lean culture” (Factor 4) articulated by different authors are statistically distinct. However, in Indian policy, these barriers are usually bundled together and viewed as a single case of “lack of knowledge.” A “train and hope” intervention would target

Factor 1, but would not improve Factor 4 whatsoever. The barriers of Funding, Technology and Infrastructure would also remain unaddressed. Therefore, Indian policy targeting Factor 1 in isolation would be expected to perform far better, at least, relative to combined “train and hope” policy frameworks that prioritise the overcoming of cultural and leadership barriers.

5.4 Measures and Benefits: Convergent Evidence for a Regulatory Strategy

The two independent rankings in this study – adoption measures and benefits – yield an RII of 0.800 for their respective highest-ranked items, both of which refer to the same policy lever. The most preferred adoption measure is the introduction of a mandatory lean construction policy and regulations. It is in line with the path the UK took following the Latham (1994) and Egan (1998) reports. Regulatory mandates, as opposed to a voluntary diffusion approach, enabled the UK construction industry to move beyond the awareness phase. Given that the study shows institutional (rather than cognitive) barriers limit the government’s adoption, especially of lean construction (Section 5.2), regulation is not merely the most preferred option among equally justifiable alternatives. It is the policy lever that best fits the study's barrier structure. It is proposed that a coordinated standard-setting approach by the Bureau of Indian Standards, the Ministry of Housing and Urban Affairs, and the Construction Industry Development Council, with progressively differentiated compliance requirements based on the scale and value of projects, would address the structural barriers that cannot be overcome with training and awareness campaigns (Aslam et al., 2024; Maru et al., 2024).

The benefits data support this conclusion through an alternate channel. As stated, improved environmental performance is the most supported benefit. This is likely the result of the Central Pollution Control Board (2017) stating that the Indian construction industry is responsible for the generation of over 300 million tonnes of construction waste every year, and in support of India’s ambitions in the Paris Agreement and the 2070 net zero target (Ramesh & Swaminathan, 2024; Tauheed, 2025). Respondents ranking environmental performance higher than cost reduction is noteworthy as cost reduction is the main benefit usually discussed in the international literature (Mossman, 2009). This suggests that the case for sustainability and the argument for the adoption of lean construction are likely to be of more relevance to Indian construction industry professionals, and that policy development and design of frameworks (that incorporate GRIHA and IGBC rating systems) focusing on environmental and climate change objectives are likely to be of more relevance and offer greater opportunities for support than a policy development and design of frameworks focusing on the cost savings. The measures and benefits data, combined, reinforce the same conclusion from two different perspectives: practitioners believe regulation is the most critical tool, and environmental performance is the most critical benefit.

6. Conclusions

This study set out to answer a question the existing India-focused literature had not yet answered at scale: how aware are Indian construction practitioners of lean concepts, how often do they apply them,

what stops them from applying them more, and what would move the needle. Drawing on 225 valid responses from government, contracting, and consulting organisations, it provides the first statistically powered, cross-organisational assessment of lean construction maturity in India and, in doing so, produces three findings that extend, rather than merely confirm, what was previously known.

The strong correlation between awareness and application ($p = 0.868$, $p < 0.001$) is a substantive finding, not a procedural one: it indicates that the gap between knowing about lean construction and practising it is narrower in India than institutional accounts of implementation failure would predict, at least at the level of individual tools and principles. This reframes where intervention effort should go — toward raising awareness of specific underused tools, which this study's data show is a fairly direct route to increasing their use, rather than toward elaborate change-management programmes designed to overcome resistance that the data do not show exists at this level of granularity.

The six-factor structure of adoption barriers — more granular than prior three- and four-factor models from South Africa and Morocco — demonstrates that “awareness deficiency” and “absence of lean culture” are empirically distinct problems, even though Indian industry discourse tends to treat them as one. Combined with the finding that government agencies face a structural, procedural barrier rather than simply an awareness gap, this points policymakers toward a multi-pronged strategy: regulatory reform for the public sector, where the binding constraint is institutional, and targeted training for the awareness-deficiency factor specifically, where the binding constraint is genuinely cognitive. A single intervention aimed at either alone is unlikely to close the gap documented in this study.

The convergence of two independently derived top-ranked items — mandatory policy as the leading adoption measure and environmental performance as the leading benefit, both at $RII = 0.800$ — gives India's policymakers a rare alignment between what practitioners say would drive adoption and what they say they value most. The recommendation for this study provides that a coordinated standard, issued jointly by the Bureau of Indian Standards, the Ministry of Housing and Urban Affairs, and the Construction Industry Development Council, is phased in around project scales and is framed to focus on environmental and climate outcomes, has a better opportunity for success than a voluntary awareness drive or a cost-savings-driven offer. This is because the coordinated standard will address both the most preferred construction standards' lever and the framing, cited by the respondents in this study.

6.1 Practical Implications

These findings support a parallel-track implementation framework rather than a single national programme. Government and policymaking bodies should prioritise regulatory reform — embedding lean performance requirements into the General Financial Rules and CPWD procurement frameworks, following the precedent set by the UK's Construction Playbook — since this study's evidence indicates that the public sector's lag is structural rather than a matter of awareness alone. Educational institutions should expand formal lean instruction in engineering and construction management curricula, targeted

specifically at the specialised analytical tools (the 5 Whys, Ishikawa diagrams, FMECA) that this study finds are disproportionately under-known relative to more generic, manufacturing-derived tools. Industry practitioners and professional bodies, particularly in the contracting and consulting segments where this study finds adoption is already comparatively advanced, should formalise mentoring and knowledge-transfer mechanisms that extend their existing lean maturity to government partners on joint public-private projects, directly addressing the cross-organisational gap this study identifies rather than waiting for top-down reform alone to close it.

6.2 Limitations and Future Research

Two limitations qualify these conclusions. First, although the sample is geographically diverse, it is skewed toward early-career professionals: 68.9% report fewer than five years of experience, while senior practitioners, who typically hold the greatest influence over an organisation's decision to adopt lean management, are comparatively under-represented. This may mean the study captures how lean concepts are understood by the workforce that will implement decisions more than by the workforce that makes them, and the two perspectives need not align. Second, the study relies on self-reported perceptions of awareness and application rather than direct observation of practice, so the strong awareness-application correlation reported in Section 4.5 reflects the relationship between what respondents believe and report about their own behaviour, not verified on-site behaviour. Future studies should adopt long-term designs that monitor the development of awareness and its application over time. This should occur as certain interventions, such as training and regulation, are implemented. Additionally, controlled field studies should incorporate self-reporting surveys and observational measures to verify if the correlation identified in this study persists when the application of these concepts is assessed beyond the self-reporting frameworks. Future studies should explore how the size and type of the project, as well as the project's geographic location, influence the results discussed in this study. Furthermore, future studies should analyse the potential for lean procurement standards to become obligatory within the frameworks of Indian law and Indian-based organisations by directly following the regulatory pathways proposed by this evidence.

Declarations

Declaration of AI Use During the preparation of this work, the author(s) used Grammarly to improve language clarity, grammar, and readability, and to assist with restructuring and tightening the discussion of findings. After using this tool, the author(s) reviewed, verified, and edited all content, data, citations, and conclusions, and take full responsibility for the accuracy, originality, and integrity of the final published work.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, MohammedShakil S. Malek (shakil250715@yahoo.co.in) upon reasonable request. The dataset comprises questionnaire responses collected from construction professionals, including contractors,

consultants, and government representatives, as part of this research. The data are not publicly available because they contain information that could compromise the privacy and confidentiality of the research participants.

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