The Impact of Lean Construction Tools on Environmental Sustainability in Morocco: A Structured Survey Analysis

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Abstract. This study explores the influence of Lean Construction (LC) techniques on environmental sustainability in the Moroccan construction industry. Known for minimizing waste and maximizing value in production systems, LC not only holds promise for improving efficiency and competitiveness but also has the potential to address environmental concerns. This study aims to fill this gap by assessing how LC can contribute to the environmental performance in Morocco based on a survey by structured questionnaire involving 330 Moroccan construction professionals. The methodology includes a comprehensive survey and analysis using SPSS V26.0. Key findings indicate a significant positive impact of LC on environmental performance, particularly in reducing material use, energy consumption, pollutant release, and non-product output. Notably, non-product output emerged as the most significantly influenced factor by LC practices. The study also reveals a differential impact of LC based on organizational characteristics, with distinct influences observed between contractors and consultants, especially in pollutant releases. These insights underscore the potential of LC in fostering environmental sustainability within the Moroccan construction sector. This survey is crucial for a more holistic understanding of LC's impact, aligning with global environmental goals and the specific needs of the Moroccan construction industry.

Keywords: Lean Construction · Survey study · Environmental Performance · Construction Industry

1 Introduction

The construction industry is a major contributor to economic growth. In Morocco, it employs almost one million people, or 9.3% of the active population, and contributes 6.6% of total value added. [1, 2]. The construction sector is important for reducing unemployment and strengthening the national economy. However, it faces several challenges, including project delays, cost overruns, and compromised quality. Additionally, it is a significant contributor to environmental pollution [3, 4].

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In Morocco, construction projects often struggle with inefficiency, largely attributed to significant delays and cost overruns [5]. This challenge is compounded by the environmental concerns arising from substantial waste generation by Moroccan construction firms. This scenario underscores the urgent need for innovative management systems that not only enhance project efficiency but also prioritize environmental sustainability by minimizing waste impact.

To address these dual objectives of performance improvement and environmental responsibility, the Moroccan construction sector is gradually adopting the LC philosophy. Originating from Lean Manufacturing principles, particularly the Toyota Production System, LC is still emerging in this context [6]. Its core goal is to execute construction projects that align with customer demands while emphasizing waste reduction and value maximization, thereby reducing environmental footprint. Additionally, LC fosters a culture of continuous improvement, actively involving individuals at all levels, from frontline employees to top management, in sustainable practices and decision-making.

In total, 330 experts in the construction field from various regions of Morocco participated in this survey. The study's focused goal is to examine how the application of LC can improve the environmental efficiency of construction projects within the Moroccan context. These insights underscore the potential of LC in fostering environmental sustainability within the Moroccan construction sector.

2 Literature Review

LC is a project delivery process that aims to maximize stakeholder value while minimizing waste and improving efficiency [7]. It emphasizes collaboration between various stakeholders in the construction process. The goal is to ensure a continuous, reliable workflow, leading to increased productivity, profitability, and innovation in the industry [8]. LC is a methodology based on the principles of lean manufacturing, which was popularized by the Toyota Production System [9]. It involves the application of various tools, methods, and systems to translate lean thinking into the construction industry. The benefits of LC include improved process efficiency, quality, timely project delivery, and cost savings. By adopting a mindset of continuous improvement, companies can achieve cumulative benefits over time. LC allows collective knowledge to solve industry problems and prepare for future challenges [10, 11].

LC, as a methodology, offers numerous benefits to the construction industry. It enhances collaboration, innovation, delivery, control, and quality [12]. By eliminating waste and improving process cycles, it reduces costs, improves quality, and increases efficiency [13]. This approach is particularly beneficial in the South African construction industry, where it has been found to reduce waste, improve material administration, and enhance the overall cost of construction projects [14]. Despite its potential, the practical application of LC in the industry is still limited, with its principles often implicitly embedded in other practices such as building information modelling, low or zero-carbon building, prefabrication, and modular construction [15–18]. A range of studies have highlighted the potential environmental benefits of LC practices. Babalola et al. [19] found that these practices can significantly reduce construction waste, while Yao et al. [20] identified prefabricated construction as particularly effective in this regard. Solaimani and Sedighi [21] emphasized the need for a more comprehensive understanding of how LC contributes to sustainability, particularly in terms of social and environmental values. Bajjou et al. [22] further underscored the importance of integrating sustainability dynamics into the LC system. These findings collectively suggest that LC practices have the potential to significantly reduce the environmental impact of construction activities.

The growing awareness of environmental issues has prompted construction organizations to concentrate not only on operational excellence but also on reassessing their operations and processes for greater environmental sustainability. This shift reflects an increasing recognition of the significance of ecological concerns in manufacturing, although research in this area remains relatively limited.

This survey evaluates four key environmental performance indicators: material usage, energy consumption, non-product output, and pollutant emissions. These indicators align with those employed in [23]'s research assessing lean management's environmental impact, which includes mitigating air emissions, managing wastewater, reducing solid waste, and curtailing the use of toxic, hazardous, or harmful materials.

3 Research Methodology

The research methodology involved conducting a survey to gather insights from professionals in Morocco's construction industry. The survey was distributed in two primary formats. Firstly, an online version was created using Google Forms and shared via LinkedIn with individuals working in both private and public sectors of the construction industry. Secondly, printed versions of the questionnaire were distributed to a range of contractors and consulting firms to ensure an acceptable response rate. The questionnaire consisted of two main sections. The initial section aimed to collect basic information about the respondents. Section 2 assessed the level of implementation of LC methods such as Just in time, Poka Yoke and Visual management in Moroccan constructions firms. While, Sect. 3 of the questionnaire examined respondents' perceptions to determine whether their have achieved any progress in terms of environmental performance measures studied (i.e., material use, non-product output, pollutant releases, energy consumption). In order to evaluate the content quality, to verify the suitability with the Moroccan context, to adjust the order of the questions and their comprehension by the respondents, semi-structured interviews with six construction professionals, with no less than ten years, were performed. Hence, the preliminary variables have been validated. Furthermore, additional items were recommended to be included, especially in the Sect. 2, to deeply explore the LC techniques such as: Prfebarication and The Failure Mode and Effect Criticality Analysis (FMECA).

In an extensive survey targeting the Moroccan construction sector, we reached out to 440 organizations involved in various construction projects, including building, road, and bridge construction. This survey was initiated in June 2023 in Morocco. Out of the contacted organizations, we received 330 responses, indicating a substantial participation rate of approximately 75%. The data from this survey was thoroughly analyzed using SPSS, specifically version 26.0 for Windows, to ensure accurate and reliable results. The research encompassed a broad spectrum of participants, reflecting various segments of the Moroccan construction sector. The diversity in the survey pool was intentional, aiming to capture a holistic view of the industry. Participants were segmented based on their affiliated organization's size. The distribution of respondents across these categories was telling; a significant 48.8% hailed from smaller firms, whereas 27.2% and 24.0% belonged to larger and medium-sized companies, respectively. This pattern indicates a prevalence of small-scale enterprises in Morocco's construction landscape. In terms of participant background, the study did not limit itself to a single sector or specialization. It drew from a pool that included various domains within both the private and public segments of the construction industry, aiming for a comprehensive understanding of stakeholder perspectives. A notable aspect of the participant demographic was the high level of education and experience. A majority, 66.1%, possessed a master's degree or higher. In terms of industry experience, 61.1% had been in the construction field for over five years. These facets of the participant demographic - the mix of company sizes, varied specializations, and high educational and experience levels - collectively enhance the credibility and depth of the study's findings.

4 Results

4.1 The Current Level of Awareness Oflean Construction Practices

The analysis of the study on the adoption of lean methods in Morocco revealed the use of 17 distinct lean techniques, at varying levels and forms. According to the data presented in Fig. 1, 39% of the respondents are not familiar with any LC methods, indicating that they have neither heard of nor implemented them. Conversely, 35% of respondents have knowledge of LC practices but have not yet incorporated them into their projects. Meanwhile, 26% of respondents are both familiar with and actively utilizing LC techniques. Interestingly, Fig. 1 also highlights that certain lean techniques are more widely adopted, with over half of the survey participants employing methods such as prefabrication and continuous improvement, noted at 63% and 54%, respectively. In contrast, many lean techniques are not widely used in the Moroccan construction sector. For example, a majority of professionals are unfamiliar with techniques such as the kanban system, Value Stream Mapping (VSM), and Poka-Yoke, with unfamiliarity rates at 63%, 58%, and 68%, respectively. This trend can be attributed to the relatively recent introduction of these methods in the Moroccan context and a lack of extensive technical training available for these specific techniques.

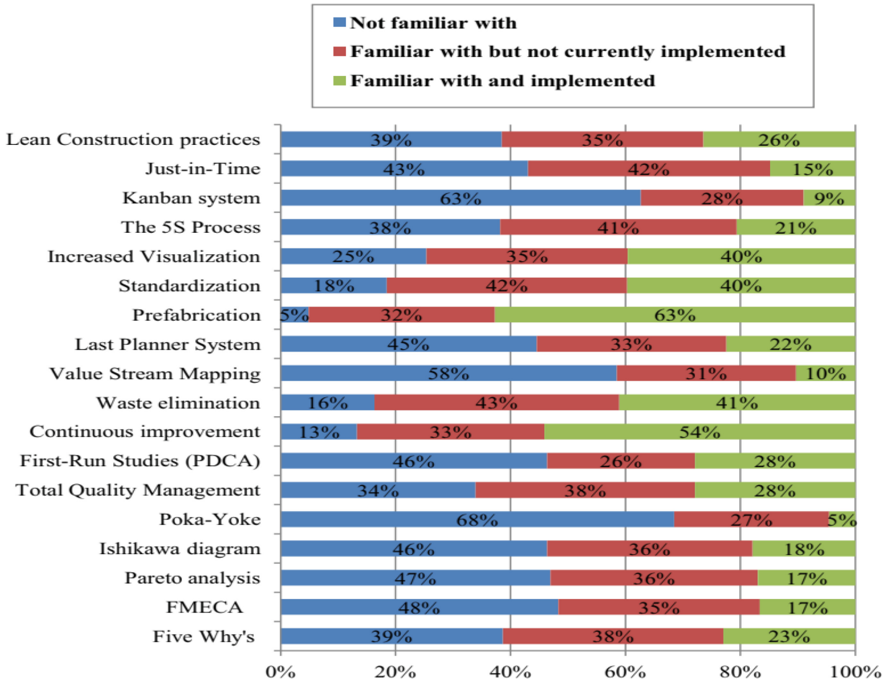

Fig. 1. The current level of awareness of lean construction practices among Moroccan construction professionals

4.2 Benefits of LC Implementation on the Environmental Performance Projects

Table 1 illustrates the prioritization of the environmental advantages associated with LC application, as deduced from the survey's average scores. The reliability of the survey's five-point scale is substantiated by a Cronbach's alpha coefficient of 0.872, which exceeds the 0.8 threshold, confirming the robustness of the measurement approach in this context.

Table 1. Ranked environmental benefits of LC implementation (Overall Cronbach's Alpha = 0.872)

	Mean	Standard deviation	Rank	Cronbach's Alpha if Item Deleted
Energy consumption	4.244	1.051	2	0.843
Pollutant releases	4.019	1.016	3	0.864
The use of material	3.787	1.036	4	0.829
Non-product output	4.417	0.931	1	0.808

The ranking of the means of various environmental factors impacted by LC practices reveals insightful trends. Non-product output, with the highest mean (4.417), is ranked as the most significant factor, highlighting its substantial influence in LC environments. This is followed by energy consumption and pollutant releases, with means of 4.244 and 4.019 respectively, indicating their considerable but slightly lesser impact compared to non-product output. The use of material, although critical, ranks lowest among the four factors with a mean of 3.7860, suggesting that while it is affected by LC practices, its impact is relatively less pronounced than the other factors. This ranking underscores the differential impact of LC on various environmental aspects, with non-product output being the most influenced, followed by energy and pollutants, and finally material usage.

The Cronbach's Alpha values associated with each environmental factor provide insights into the internal consistency and reliability of the dataset when considering the removal of each factor. Non-product output, with a Cronbach's Alpha of 0.8808, indicates the highest reliability, suggesting that its exclusion would most significantly affect the consistency of the environmental impact assessment. These values collectively suggest a robust and consistent dataset but also highlight the varying degrees of impact that the exclusion of each environmental factor would have on the reliability of the environmental assessment in the context of LC.

Given that the overall Cronbach's Alpha for the study is 0.872 is higher than the individual Alpha values for each item (environmental factor), we can infer that the dataset as a whole exhibits high internal consistency and reliability in assessing the environmental impacts of LC. This overall Alpha value is a measure of how well the set of items (in this case, environmental factors) are interrelated, indicating a strong degree of coherence and reliability in the measurement of the study's constructs.

4.3 Spearman Rank Correlation

To evaluate the relationship and its strength and direction between two groups of clusters, the non-parametric Spearman rank correlation was employed. This method calculates the Spearman rank correlation coefficient (rs) to quantify the correlation. The coefficient can be computed as follows:

$$r_s = 1 - \frac{6\sum d^2}{N\left(N^2 - 1\right)} \tag{1}$$

where:

The Spearman's rank correlation coefficient, denoted as rs, is a statistical measure. It is calculated based on the differences in rankings (d) assigned by two respondents for a specific item, and N represents the total number of rank pairs. The value of rs can vary from $+1$ to -1, where $+1$ signifies a perfect positive relationship, -1 indicates a perfect negative relationship, and a value of 0 implies no correlation between the rankings.

Table 2. Spearman's rank inter-correlation test

			Energy consumption	Pollutant releases	The use of material	Non-product output
Spearman's coefficient	Energy consumption	Correlation coefficient	1.000	0.504**	0.547**	0.433**
		Sig. (bilateral)	.	0.000	0.000	0.000
		N	330	330	330	330
	Pollutant releases	Correlation coefficient	0.504**	1.000	0.736**	0.455**
		Sig. (bilateral)	0.000	.	0.000	0.000
		N	330	330	330	330
	The use of material	Correlation coefficient	0.547**	0.736**	1.000	0.403**
		Sig. (bilateral)	0.000	0.000	.	0.000
		N	330	330	330	330
	Non-product output	Correlation coefficient	0.433**	0.455**	0.403**	1,000
		Sig. (bilateral)	0.000	0.000	0.000	.
		N	330	330	330	330

** Correlation is significant at the 0.01 level (two-tailed).

To study the level of inter-correlation between the different items, a Spearman rho correlation matrix was drawn up. In Table 2, cells highlighted in black in the matrix indicate a high correlation (Spearman correlation coefficient $>$ 0.5); between Energy consumption and (Pollutant releases and The use of material); between Pollutant releases and The use of material. Cells highlighted in grey indicate moderate correlation (0.3 $<$ pearman correlation coefficient $\leq$ 0.5), between Non-product output and (Energy consumption, Pollutant releases, and The use of material). Most correlations were found to be significant at a two-sided confidence level of 99% (**). Consequently, the data set could be analyzed as a whole for one way test Anova.

4.4 One Way Anova Analysis

The sample was divided into four distinct subgroups, each based on specific organizational characteristics, allowing for a comprehensive analysis of the diverse aspects of the construction industry, as illustrated in Table 3. Subgroup 1 was categorized according to the type of organization, distinguishing between contractors and consultants. Subgroup 2 was classified based on specialization fields, including bridge and road projects, and building projects. Subgroup 3 was delineated based on the activity area, distinguishing between public and private sectors. Finally, subgroup 4 was delineated by the size of the organization, with distinctions made for small, medium, or large organizations.

Table 3. One way Anova test (items: environmental benefits)

Identifier	According to the type of organization	According to the field of specialization	According to the area of activity	According to the size of the organization
	P-value	P-value	P-value	P-value
energy consumption	0.069	0.944	0.798	0.693
pollutant releases	0.012*	0.272	0.869	0.591
The use of material	0.129	0.578	0.996	0.602
non-product output	0.160	0.236	0.982	0.673

Based on an Anova test, all p-values are above 0.05 for sub-groups 2, 3, and 4 indicating that field of specialization, activity area and type of organization do not significantly impact the scores given to the four items listed in the current survey, as shown in Table 3. However, it's essential to highlight that the only statistically significant result in our analysis is for pollutant releases ($p = 0.012$), a level which is lower than the typical alpha threshold of 0.05. This strongly suggests that the type of organization indeed has a significant impact on pollutant releases. To further elaborate on this finding, we can examine the mean scores for pollutant releases among different types of organizations. On average, contractors have a mean score of 4.250, whereas consultants have a lower mean score of 3.914. The reason for this observed difference in pollutant releases between contractors and consultants could be attributed to several factors. One possible explanation might be that contractors, due to their direct involvement in various construction and industrial activities, could be subject to more stringent environmental regulations and monitoring, which motivates them to better manage and mitigate pollutant releases. Consultants, on the other hand, may have less direct control over on-site operations and, therefore, may not be as focused on pollution reduction measures.

Additionally, contractors may have more resources and expertise dedicated to environmental management, given their hands-on role in projects, whereas consultants might prioritize other aspects of their work. It is also possible that contractors have adopted more advanced pollution control technologies and practices due to their greater exposure to environmental compliance requirements.

Further research and a detailed analysis of specific operational practices and policies within these types of organizations could provide deeper insights into the reasons behind this significant difference in pollutant releases. The other factors (energy consumption, use of material, and non-product output) are not significantly affected by the type of organization.

5 Conclusion

The survey aimed to understand how LC can contribute to improving environmental performance in Morocco, specifically by reducing negative impacts such as material use, energy consumption, pollutant release, and non-product output. The study's results demonstrate that LC philosophy has significant potential to enhance environmental sustainability in the Moroccan construction industry. The mean values for all evaluated environmental factors indicate that LC practices can have a significant positive impact. The findings show that LC has a differential impact on various environmental aspects. Non-product output had the highest mean value and was identified as the most significantly influenced factor, followed by energy consumption and pollutant releases. Material use, while important, had a relatively less pronounced impact compared to the other factors. The study also analyzed the role of organizational characteristics in LC implementation and their impact on environmental performance. The analysis showed that the type of organization, such as contractors versus consultants, could significantly influence certain environmental factors, particularly pollutant releases. This indicates that different types of organizations may adopt and benefit from LC practices in distinct ways. In conclusion, the paper argues that LC methodologies can substantially contribute to environmental sustainability in the Moroccan construction industry. The study's comprehensive statistical analysis supports the conclusion that LC can significantly reduce the environmental impact of construction activities. The findings can inform policymakers and industry leaders in Morocco and other developing countries about the potential environmental benefits of LC. This could lead to the development of targeted strategies and policies to promote LC methodologies in the construction sector. In addition, the study provides a benchmark for environmental performance in the Moroccan construction industry. Organizations can use these findings to monitor their performance and strive for continuous improvement in environmental sustainability.

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