ASSESSING THE IMPACT OF LEAN MANUFACTURING ON OPERATIONAL PERFORMANCE IN LIBYA: INSIGHTS FROM LEBDAH CEMENT FACTORY

Faraj Eldabee*, Al-Hussen Algornazy*, Yousef Amer**

*Department of Mechanical and Industrial Engineering
Faculty of Engineering, University of Tripoli, Libya
**Adelaide University, Adelaide, Australia
Email: f.eldabee@uot.edu.ly

Received 10 September 2025; Revised 7 October 2025; Accepted 14 October 2025; Published 10 November 2025

الملخص

تبحث هذه الدراسة في تطبيق التصنيع الرشيق (LM) في مصنع لبدة للإسمنت (LCF) في ليبيا، لتقييم أثره على الأداء التشغيلي. حيث بحثت الدراسة تطبيق مبادئ التصنيع الرشيق باستخدام استبانة مُنظّمة تضمنت أدوات تقليل الهدر السبعة، وُزّعت على 118 موظفاً. وكشف التحليل الإحصائي عن وجود علاقة إيجابية قوية بين تبني التصنيع الرشيق وأداء العمليات في المصنع (معامل بيرسون= 0.83؛ β = 0.711، p < 0.001). وتُبين النتائج أنه على الرغم من التحديات القائمة، فإن التصنيع الرشيق يُحسّن من كفاءة الإنتاج في صناعة الإسمنت الليبية بشكل ملحوظ. كما تُساهم هذه الدراسة في إثراء الدراسات التجريبية المحدودة المتعلقة بالتصنيع الرشيق في الاقتصاديات النامية، وتُقدّم إرشادات عملية للمدراء الساعين إلى التميز التشغيلي في البيئات محدودة الموارد.

ABSTRACT

This study investigates the implementation of lean manufacturing (LM) in the Lebdah Cement Factory (LCF), Libya, to assess its impact on operational performance. Using a structured questionnaire distributed to 118 employees, the study examined the application of LM principles, particularly in minimising the seven wastes. Statistical analysis revealed a strong positive relationship between LM adoption and process performance (Pearson $r = 0.83$; $\beta = 0.711$, $p < 0.001$). The findings highlight that despite contextual challenges, LM significantly improves production efficiency in the Libyan cement industry. This study contributes to the limited empirical literature on LM in developing economies and offers practical guidance for managers seeking operational excellence in resource-constrained environments.

KEYWORDS: Lean manufacturing; Cement Factory; Performance; Production processes; Questionnaire; waste; Statistical analysis.

INTRODUCTION

The concept of lean production originated from the Toyota Production System (TPS) in the 1950s, with the central aim of achieving more with fewer resources by eliminating non-value-added activities and improving overall efficiency [1, 2, 3]. LM has since gained significant global attention, offering proven benefits in enhancing operational performance, reducing costs, and increasing customer satisfaction. Despite its widespread adoption, LM remains underexplored in developing countries, including Libya, where industrial organisations often face challenges such as limited resources, cultural resistance to change, and insufficient training infrastructure.

Within the Libyan cement sector, the implementation of LM has the potential to address inefficiencies and improve productivity, yet empirical research in this area is scarce. This study seeks to fill this gap by assessing the impact of LM implementation on operational performance at the Lebdah Cement Factory (LCF). Specifically, the research aims to identify the key types of waste in the factory's production processes, measure the extent to which LM principles are applied, and evaluate the relationship between LM adoption and operational performance.

By pursuing these objectives, the study contributes to the broader LM literature by extending the analysis of LM–performance relationships into the under-researched context of a developing country. At the same time, it provides practical insights for managers in Libya and similar economies, demonstrating how LM can be leveraged as a strategic approach to improving efficiency in resource-constrained industrial environments.

AN OVERVIEW OF LEAN MANUFACTURING

LM is a production philosophy centred on eliminating all forms of waste while simultaneously increasing customer value. In essence, lean is about delivering more value to customers with fewer resources. A lean organisation recognises customer needs and continuously refines its core processes to enhance efficiency and responsiveness [4, 5, 6]. The seven commonly recognised categories of waste include overproduction, transportation, waiting time, excess inventory, unnecessary motion, over-processing, and defects [1].

Over the past decades, numerous studies have explored the role of LM in improving operational performance across industries. A variety of tools and techniques have been introduced to support its implementation. For example, Value Stream Mapping (VSM) has been proposed as a tool to enhance flexibility in the Libyan metal cans sector, with results showing that VSM can significantly improve manufacturing efficiency in a developing country context [7]. Similarly, a conceptual model linking LM practices to business performance was tested within Libyan manufacturing industries using structural equation modelling (SEM). The study demonstrated that LM contributes positively to employee development, which in turn drives business performance [8].

Other research has focused on the barriers and enablers of LM adoption in Libya. A survey of 65 Libyan industrial companies highlighted key challenges, including insufficient economic systems, weak infrastructure, and a lack of training in quality techniques [9]. These findings underscore that while LM holds considerable promise for improving productivity and efficiency, its implementation in Libya requires overcoming structural, financial, and cultural obstacles. In another research, the current status of the implementation levels of JIT key-factors within the Libyan industries was investigated using a survey methodology. The results illustrated that the implementation status of the JIT key-factors and their sub-elements are found to be in the modest levels across all the surveyed organisations, thereby indicating to opportunities for eliminating waste and improving the value chain [10].

METHODOLOGY AND DATA COLLECTION

A structured questionnaire was designed to capture the key factors influencing the successful implementation of Lean Manufacturing (LM) principles within the Lebdah

Cement Factory (LCF). The instrument was based on a five-point Likert scale to ensure measurement consistency and accuracy. Table (1) presents the scale used to interpret responses, ranging from strongly agree (5) to strongly disagree (1), with corresponding mean values and relative weights.

Table 1: Illustration of the 5-Point Likert Scale.

Answer	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Grade	1	2	3	4	5
Mean	Less than 1.80	1.8 to 2.59	2.6 to 3.39	3.4 to 4.19	Greater than 4.2
Relative weight (%)	Less than 36	36 to 51.9	52 to 67.6	68 to 83.9	Greater than 84

The questionnaire consisted of two main sections. The first section collected demographic data about respondents and the organisation, while the second addressed the main research variables and their associated sub-dimensions. As shown in Table (2), the LM dimension focused on the seven categories of waste (over-processing, waiting time, transportation, motion, inventory, over-production, and defects), comprising 34 items in total. The second variable assessed the performance of the factory's production operations through 12 items, yielding a total of 46 measurement items.

Table 2: Distribution of the study tool's items on its component variables and dimensions.

Variable	Dimensions	Number of Items
1. Types of Waste	Over-processing	5
	Waiting time	5
	Transportation	5
	Motion	5
	Inventory	4
	Over-production	5
	Defects	5
	Total number of the first variable items	34
2. Performance of the factory's production operations		12
Total		46

DISCUSSION AND ANALYSIS

Validity of the Study Variables and Dimensions

Table (3) presents the results of the validity tests for the study variables and dimensions. The findings show that all correlation coefficients were statistically significant at the 0.05 level. The lowest correlation value was 0.635 for the inventory dimension (storage of materials), while the highest was 0.778 for the transportation dimension (unnecessary transfer of materials). Importantly, all correlation coefficients exceeded the generally accepted threshold of 0.40, confirming the internal consistency and validity of the research instrument.

These results indicate that the questionnaire items were strongly aligned with the constructs they were intended to measure. In particular, the high correlation values for transportation and motion reflect the practical significance of material handling and movement efficiency within the cement factory's operations. Conversely, the relatively lower correlation for inventory suggests that material storage issues, while relevant, may not be as strongly perceived by employees as other forms of waste. Overall, the results confirm that the measurement tool is valid for capturing the dimensions of lean manufacturing and operational performance in the context of LCF.

Table 3: Validity of the study variables and dimensions.

Study variables	Study Dimensions	Number of Items	Pearson Correlation	Significance level
1	Over-processing	5	0.702	$3.0396\text{x}10^{-19}$
	Waiting time	5	0.687	$3.3014\text{x}10^{-18}$
	Transportation	5	0.778	$3.039\text{x}10^{-19}$
	Motion	5	0.731	$9.8336\text{x}10^{-26}$
	Inventory	4	0.635	$1.7613\text{x}10^{-21}$
	Over-production	5	0.701	$4.9022\text{x}10^{-15}$
	Defects	5	0.656	$3.4001\text{x}10^{-19}$
	Total number of items	34	0.70	$7.3032\text{x}10^{-15}$
2	Performance of the factory's production operations.	12	0.650	$2.7954\text{x}10^{-16}$

Reliability of the Study Tool

Reliability refers to the degree to which a measurement instrument consistently produces stable results when applied to the same individuals under similar conditions. A reliable tool reduces the influence of random error and ensures that the data collected accurately reflects the constructs being measured. Among the various approaches to testing reliability, Cronbach's Alpha is the most widely used. This coefficient ranges from 0 to 1, with higher values indicating stronger internal consistency. In addition, the Guttman Split-Half Coefficient is often employed as a complementary measure to assess the stability of responses.

Table (4) presents the reliability results for the study variables and dimensions. The Cronbach's Alpha coefficients ranged from 0.822 (Inventory) to 0.928 (overall LM dimensions), with an overall reliability score of 0.936. These values exceed the generally accepted threshold of 0.70, confirming that the questionnaire items demonstrate strong internal consistency. Similarly, the Guttman Split-Half coefficients ranged from 0.726 to 0.896, with an overall reliability of 0.811, further supporting the stability and homogeneity of the responses.

Table 4: Results of reliability tests of the study variables and dimensions.

Study Variables	Study Dimensions	Number of Items	Cronbach's Alpha Factor	Guttman Split-Half Coefficient
1	Over-processing	5	0.867	0.825
	Waiting time	5	0.858	0.848
	Transportation	5	0.915	0.896
	Motion	5	0.871	0.827
	Inventory	4	0.822	0.726
	Over-production	5	0.878	0.865
	Defects	5	0.891	0.863
	Total number of items	34	0.928	0.820
2	Performance of the factory's production operations.	12	0.854	0.764
Overall Stability		46	0.936	0.811

Demographic Data

Table (5) summarises the demographic characteristics of the respondents working in production-related roles at the Lebdah Cement Factory (LCF). The results indicate that the workforce is relatively well qualified, with most respondents (58.7%) holding qualifications above the intermediate diploma level. Notably, 41.3% of respondents had obtained a bachelor's degree, while a smaller proportion held higher diplomas (15.7%) or intermediate diplomas (18.2%). Only a minority (23.1%) had completed high school as their highest qualification, and no respondents reported holding a master's or doctoral degree.

In terms of work experience, the data show a mature workforce, with 35.5% of respondents having more than 21 years of experience in the industry. A further 26.4% reported less than five years of experience, indicating the presence of a younger cohort within the organisation. Smaller groups fell within the mid-range categories of 5–10 years (18.2%), 11–15 years (11.6%), and 16–20 years (8.3%).

Regarding job roles, most respondents (74.4%) were employees directly engaged in operational tasks. Supervisory and leadership positions were represented to a much lesser extent, with 9.1% team leaders, 7.4%-unit heads, 6.6% section heads, 1.7% department managers, and only one general manager (0.8%). This distribution highlights that most insights were drawn from employees at the operational level, providing a bottom-up perspective on the implementation of lean manufacturing practices.

Table 5: The characteristics of the respondents.

Variable Factors		Frequency	Percent (%)
Educational Qualification	High School	28	23.1
	Intermediate Diploma	22	18.2
	Higher Diploma	19	15.7
	Bachelor's Degree	50	41.3
	Master's Degree/PhD	0	0
	Other	2	1.7
Years of Experience	Less than 5	32	26.4
	5-10	22	18.2
	11-15	14	11.6
	16-20	10	8.3
	21 or more	43	35.5
Job Position	General Manager	1	0.8
	Department Manager	2	1.7
	Section Head	8	6.6
	Unit Head	9	7.4
	Team Leader	11	9.1
	Employee	90	74.4

Results and Analysis of the Study Variables and Dimensions

Table (6) presents the descriptive statistics for the study variables and their associated dimensions, based on responses from managers, supervisors, and technical workers at LCF. The results indicate that the mean score for the first variable, types of waste, was 3.55 out of 5, corresponding to a relative weight of 71.0%. The second variable, performance of production operations, achieved a slightly higher mean of 3.64 out of 5, with a relative weight of 72.8%. Both results suggest that respondents expressed a generally high level of agreement regarding the application of lean manufacturing principles and their impact on performance.

Table 6: Results of the analysis of the study variables and dimensions.

Study Variables	Number of Items	Mean	Standard Deviation	Relative Weight (%)	Ranking
Over-processing	5	3.46	0.79	69.2	**5**
Waiting time	5	3.62	0.74	72.33	**3**
Transportation	5	3.74	0.85	74.78	**1**
Motion	5	3.36	0.82	67.17	**7**
Inventory	4	3.63	0.71	72.60	**2**
Over-production	5	3.61	0.76	72.13	**4**
Defects	5	3.46	0.84	69.12	**6**
First Variable: Types of Waste	34	3.55	0.55	71.02	
Second Variable: Performance of the factory's	12	3.64	0.60	72.84	

production operations					

Within the dimensions of waste, the most critical factor identified was transportation waste, which achieved the highest mean score of 3.74 (relative weight 74.8%), ranking first among all dimensions. This finding highlights the significant challenges associated with the unnecessary transfer of materials within the cement factory, reflecting broader logistical inefficiencies in Libyan manufacturing environments. Inventory waste ranked second (mean = 3.63), followed closely by waiting time (mean = 3.62), and over-production (mean = 3.61).

By contrast, motion waste was rated lowest, with a mean of 3.36 (relative weight 67.2%), suggesting that respondents perceived inefficiencies related to worker or equipment movement as less critical compared to material handling and storage issues. Over-processing and defects were rated moderately, with means of 3.46 each.

Overall, the results confirm that lean manufacturing principles are both recognised and valued within the organisation, with transportation, inventory, and waiting time perceived as the most pressing areas for improvement. These findings align with prior studies on LM in developing economies, where inefficient material flows and inadequate infrastructure frequently emerge as the dominant sources of waste.

Testing the Study Hypothesis

Table (7) clearly shows that the application of Lean Manufacturing (LM) principles has a statistically significant impact on improving operational performance at LCF. The correlation coefficient (R) was 0.832, with a significance level of 0.000, indicating a strong positive relationship between LM implementation and operations performance. The coefficient of determination (R^2) was 0.693, which implies that approximately 69.3% of the variance in operations performance can be attributed to changes in the application of LM principles.

The regression coefficient (β) was 0.711 at a significance level of 0.000. This indicates that, when other variables are held constant, a one-unit increase in the application of LM principles is associated with a 0.711-unit improvement in operations performance.

Therefore, the main hypothesis is supported: there is a statistically significant impact of applying LM principles on the enhancement of production operations at LCF, at a significance level of $\alpha \leq 0.05$. This outcome reflects the factory's commitment to implementing lean practices, which is evident in its strong performance both locally and internationally.

Table 7: Results of correlation and simple regression analysis to test the main hypothesis.

Hypothesis	Correlation coefficient (R)	Coefficient of determination (R^2)	Calculated value (F)	Degree of freedom (DF)	Regression coefficient (β)	Significance level (α)
A significant relationship exists between waste types and production	0.832	0.693	87	120	0.711	7.464×10^{-16}

performance in the factory						

CONCLUSIONS & RECOMMENDATIONS

This study demonstrated that applying Lean Manufacturing (LM) principles significantly improves operational performance at LCF by reducing various types of waste. Respondents reported high levels of process performance, confirming a strong positive relationship between LM implementation and production efficiency. The findings indicate that LM enhances both the effectiveness and overall productivity of the factory. Future research could explore additional LM tools to identify potential gaps or limitations in current practices, providing further insights for optimising production processes and sustaining competitive advantage.

REFERENCES

[1] Tourki, T. (2010). Implementation of Lean within the cement industry, PhD thesis, De Montfort University.

[2] Hokoma, R. and El-Dubei, F. (2010). Minimizing inventory costs throughout the supply chain within a cement factory: a case study, MEQA,4th annual congress, Dubai, UAE.

[3] Hajmohammad, S., Vachon, S., Klassen, R., and Gavronski, I. (2012). Lean management and supply management: their role in green practices and performance, *Journal of Cleaner Production*, 39, 312-320.

[4] Hokoma, R. (2016). Survey Investigation of just-in-time implementation and its implications for management in four key industries within Libya, *International Journal of Engineering Research & Technology*, 5(1), 116-121.

[5] Ohno, T. (2019). Toyota production system: beyond large-scale production, New York. Productivity press. e-book.

[6] Hokoma, R. (2016). A way forward for implementing just-in-time techniques within oil & gas industries: domestic appliances, *Journal of Engineering Research*, Faculty of Engineering, University of Tripoli, 21.

[7] Razig, A. J., Khalifa, A. G. & Bouhawish, W. Y. (2021). Application of value stream mapping (VSM) in Libya: a lean manufacturing case study, *International Research Journal of Engineering and Technology*, 8(1), 1604-1608.

[8] Ataalah, A., Hasnan, K., Mohammad, M., Ahmad, M. F. and Alkalani, A. (2016). Relationship Between Lean Manufacturing and Business Performance: A Conceptual Model Based on Libyan Manufacturing Industries, *Journal of Engineering and Applied Sciences*, 11, 8642-8647.

[9] Abduelmula, M., Birkett, M. and Connor, C. (2017). A mixed method approach to investigate the lack of lean manufacturing implementation in Libya, *International Journal of Technology and Engineering Studies*, 3(3), 111-116.

[10] Hokoma, R. and Amaigl, H. (2019). A detailed survey of just-in-time implementation status within Libyan cement industry, and its implication for operations management, *Independent Journal of Management & Production*, 10(3), 1081-1093.