MINAR International Journal of Applied Sciences and Technology
ISSN: 2717-8234
Article type: Research Article

Received: 02/10/2022 **Accepted:** 20/10/2022 **Published:** 01/12/2022

POTENTIALS OF EMPLOYING LEAN CONSTRUCTION IN IRAQ

Jamal S. NAYYEF [1]
Istanbul Gedik University, Turkey
Redvan GHASEMLOUIA
Istanbul Gedik University, Turkey
Zeyad S. M. KHALED
Dijlah University College, Iraq

Abstract:

Successful construction projects are those to be completed within the planned time, cost and quality, in addition to minimizing waste, pollution and energy consumption. It is believed that adopting lean principles in the construction industry can help a lot in achieving these goals. This research aims at studying the benefits, obstacles and readiness to adopt lean construction in Iraq and the actions needed. A questionnaire was designed based on extensive review of relevant literature and then directed to (123) professionals involved in the Iraqi construction industry. The results were statistically analyzed and tested and found to be valid and reliable. Contradictions of very few aspects were then discussed and clarified through direct interviews with (10%) of the questionnaire respondents. The research revealed that the Iraqi construction industry is in need of all potential benefits that lean construction can provide through value maximization and using modern construction techniques. The research also revealed that the main obstacles are lack of expertise, skills, awareness and knowledge in lean principles and poor culture related to waste identification and control. Concerning the readiness success factors, more emphasis was made to the integration of design, manufacture and construction and life-cycle engineering. Finally, proactive actions were suggested on national and institutional scales taking into account that the major role to shift to lean construction rests with the government and the construction sector leaders.

Keywords: Lean Thinking, Lean Production, Lean Construction, Construction Industry, Construction Projects.

http://dx.doi.org/10.47832/2717-8234.13.19

[1] engjamal70@gmail.com, https://orcid.org/0000-0002-7089-0243

Introduction:

The Iraqi infrastructure has been exposed to destruction as a result of wars since 1980's and to deterioration due to the economic blockade (1991-2003). Furthermore, the governments formed after 2003 fail to activate this industry, so there is an enormous shortage in all types of public services. Moreover, there is a lack of qualified private contractors and governmental supervisory staff, while both are using traditional technology and outdated techniques. Therefore, many problems are encountered by the Iraqi construction industry including time and cost overrun and low quality accompanied with high rates of materials and energy waste. Meanwhile, this important and vital industry is still hesitated to adopt lean construction and to gain its benefits in order to mitigate these defects. This necessitates studying the potentials of adopting lean construction in Iraq and proposing actions (**Mohammed, and Jasim, 2018**).

Lean thinking focuses on decreasing waste in materials and processes, starting with design and proceeds through production and beyond. It is also about enhancing speed, efficiency, and quality. This necessitates a significant amount of effort to cultivate a lean culture among the relevant constituencies, which, in turn, results in increased value for all stakeholders (**Blokdyk, 2019**).

Many advantages in adopting lean construction have been recognized by many researchers. These benefits can be summarized as: eliminating waste, lowering costs, increasing productivity, shortening duration, reducing inventory, enhancing quality, and improving safety (**Womack and Jones, 2010; Vilasini et al., 2011; Modi and Thakkar, 2014; Akinradewo et al., 2018**).

According to several studies carried out in other countries, barriers to adopt lean construction can be categorized in six primary groups including: managerial, financial, educational, governmental, technical, and human attitude (**Olatunji, 2008; Jorgensen and Emmitt, 2008; Abdullah et al., 2009; Mossman, 2009; Alinaitwe, 2009; Forbes and Ahmed, 2020**).

According to (**Le Gratiet, 2017**), the best practices needed for Lean Construction are: setting clear objectives for the delivery process, maintaining maximum performance at the project level, concurrent design of processes and products, and applying production control all along the project life. These practices mean that lean construction management performs on the project holistic scale rather than on individual activity scale. To do so, proper techniques is needed. The widely implemented lean construction techniques found in the relevant literature can be summarized in the following: The Last Planner System (**Ballard and Tommelein, 2016**), Just-in-Time (**Enshassi et al., 2020**), The Japanese 5S Method (**Gao and Low, 2014**), Poka-yoke Mistake-Proofing (**Tommelein and Demirkesen, 2018**), Visual Management (**Singh and Kumar, 2020**), Target Value Design (**Khah et al., 2019**), Value Stream Mapping (**Demirkesen, 2021**), The 5 Whys for Root Cause Analysis (**Ansah et al., 2016**), Gemba Walks (**Womack, 2013**) and Daily Huddle Meetings (**Enshassi et al., 2019**).

Literature Review

Recent studies, that are relevant to this research, are summarized in Table (1).

Table 1: Summary of relevant recent studies

Sarhan et al. in (2017)	Studied the barriers to implement lean construction in the KSA construction industry using a questionnaire survey to identify and rank the barriers.	The high ranked barriers found were: persistence of outdated practices, disapproving organization culture, absence of relevant technical skills and lack of knowledge of lean principles.
Small et al. in (2017)	Examined the chances for integrating the lean concepts in the constructing industry of Dubai using a questionnaire survey addressed to professionals.	The study confirmed the suitability of the techniques previously proposed by (Kanafani, 2015) to overcome the barriers.
Dede in (2018)	Investigated waste sources and consequences in the Turkish construction sector. Five construction companies were interviewed about the most common waste reasons.	It was found that waste causes might initiate at design, procurement and execution stages especially inefficient planning and control which may be avoided by employing lean techniques accompanied with BIM.
Mustonen in (2018)	Studied the contribution of a lean construction technique called 'Takt scheduling', to site management activities through interviews and site observation.	It was found that 'Takt scheduling' shortened lead time and provided obvious framework for ensuring anticipated execution with better constructability and unified objectives.
Yusof in (2018)	Developed a lean design process for building projects using a questionnaire survey to obtain opinions of practitioners on current practices of mitigating design-related waste.	It was found that innovation in the building design process is essential and a list of construction-related wastes can also be previously developed.
Albanna in (2019)	Developed an instrument to measure workers' comprehension of lean ideas in the construction industry of Lebanon using a questionnaire survey.	I was found that workers suffer from misunderstanding of waste-related concepts and waste types, lean pull production practices and knowledge, site organization and standardization concepts.
Amunzu in (2020)	Conducted an investigation of construction managers' comprehension of lean thinking in the Northeast United States. A qualitative approach was used to identify an insight study.	The results highlighted the strengths of the lean thinking framework of the Toyota Production System (TPS) in the construction industry.
Yuan et al. in (2020)	Conducted a study on manufactured lean construction in China covered the evaluation of organizational capability against barriers, based on literature analysis, field survey, questionnaire surveys and interviews.	The barriers were found to be related to management, skills and knowledge, the construction industry itself, supply chain and degree of prefabrication.
Gupta et al. in (2020)	Carried out a review on the barriers to lean constructing implementation in India. A survey of previous studies was conducted.	The top barriers identified were lack of experience and information sharing, lack of training and awareness, and lack of technical skills.

Koohestani et al. in (2020)	Conducted a questionnaire survey to find a way to implement lean construction in Iran.	It was found that institutional and project-related factors have a greater impact on the lean construction adoption than external factors.
Demirkesen and Bayhan in (2020)	Developed a model for lean implementation in the constructing industries in Turkey. A questionnaire survey was carried out using Delphi method.	The developed model showed that lean training, accessibility of lean tools and methods were the chief elements that have effects upon the success of lean implementing.
Aslam et al. in (2020)	Explored the factors of implementing lean construction for rapid initial success in Pakistan through a self-structured questionnaire.	The results indicated that organizations should start lean construction with a clear goal of improving results and processes through commitment and collaboration by all project participants.
Al-Balkhy et al. in (2021)	Evaluated the challenges to lean construction adoption in Jordan using a questionnaire survey.	It was found that all stakeholders have similar perspectives on the challenges.
Watfa and Sawalha in (2021)	Carried out a research in the UAE on the critical success factors for lean construction. A survey was conducted by means of a questionnaire and the sample consisted of professionals.	It was found that lean construction principles are not extensively adopted in the UAE, with just 28% of the enterprises assessed know about or already employ lean techniques.

Methodology

A questionnaire was designed based on extensive literature review on lean construction concepts, techniques, challenges and success factors in order to reach Iraqi experts opinions. The questions were classified into parts and sections in order to facilitate feedback on the possibility of applying lean construction in Iraq by investigating and ranking the benefits, obstacles, readiness success factors, and the actions needed based on Likert's five degrees scale.

The questionnaire was directed to (160) professionals from Public and Private Sectors including governmental administrations, contracting companies, consultancy bureaus, laboratory centers, material manufacturers and suppliers, equipment providers and academics. However, (123) responses were received. The findings were displayed and examined using applicable statistical tests. The gathered answers included description and ratings of various factors. Descriptive statistical measures and ranking were conducted. The results were subjected to statistical analysis using SPSS (Statistical Package) V.24.

The five-point Likert scale was transformed to relative importance indices (RII) for each factor in the questionnaire using Eq. (1) (**Ozdemir, 2010**):

$$RII = \left(\frac{\sum W}{A*N}\right) \qquad \text{...............} \quad (1)$$

where:

W: is the weight given by the respondents within the range of (0 - 4),

A: is the highest weight given by the respondents (for each factor) and

N: is the total number of respondents.

The statistical measures used included the following:

- Mean Percentage Error (MPE):

$$MPE = \{\sum \frac{A-E}{A}/n\} * 100\%$$ …………… (2)

where:

A: actual value,

E: estimated value or predicted value, and

n: total number of cases.

- Root Mean Squared Error (RMSE):

$$\mathbf{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(\mathbf{E}-\mathbf{A})^2}{\mathbf{n}}}$$ ……………

(3)

- Mean Absolute Percentage Error (MAPE):

$$MAPE = (\sum \frac{|A-E|}{A} * 100\%)/n$$ …………… (4)

- Average Accuracy Percentage (AA%):

AA% = 100% - MAPE …………… (5)

- The Coefficient of Determination (R^2).

- The Coefficient of Correlation (R).

- The Cronbach's coefficient (alpha) measure was used to check the reliability and validity of the results using formula (6) for reliability test and formula (7) for validity test. The values between (0.0) to (1.0) are considered as the normal range for Cronbach's coefficient (alpha) (**Gunduz and Abu-Hassan, 2017**).

$$\alpha = \frac{K}{K-1}[1 - \frac{\sum_{i=1}^{K} S_i^2}{S_t^2}]$$ ……………

(6)

$$V = \sqrt[2]{\alpha}$$ …………… (7)

where:

K: is the number of items in a group.

S_i^2: is the variance associated with item (i).

S_t^2: is the variance associated with the sum of all (k) item scores

- Shapiro-Wilk test was carried out to identify whether the results of the questionnaire are normally distributed. Normal distribution of data is attained when the P-value of Shapiro-Wilk test is more than (0.05) and the skewness and kurtosis measures are close to zero. A small departure from zero is found in real world and it is statistically acceptable as long as the standard error is very much smaller than variable values i.e. the Z-values related to skewness and kurtosis is between (-1.96 and 1.96) using formulae (3.8) and (3.9) (**Hasan, 2015**).

$$Z_{\mathbf{skewness}} = \frac{\text{Skewness}}{\text{Std.errors}}$$ ……………

(8)

$$Z_{\mathbf{kurtosis}} = \frac{\text{kurtosis}}{\text{Std.errors}}$$ ……………

(9)

Further questions aroused after collecting and analyzing the questionnaire results, therefore, they were elaborated through interviews with (10%) of the respondents using a structured interview sheet. The interviews were held face-to-face with discussion being conducted.

The Questionnaire Results

The first part of the questionnaire was designated to disclose information about the participants and their organizations. The results are summarized in Table (2).

Table 2: General information about the respondents

Organization work sector	Public		Private	
	108 (87.8%)		15 (12.2%)	
Organization type of business	Client	Consultant	Contractor	
	35 (28.5%)	41 (33.3%)	24 (19.5%)	
	Manufacturer	Supplier	Academics	
	2 (1.6%)	13 (2.4%)	8 (14.6%)	
Organization field of practice	Buildings	Highways & Bridges	Water Supply & Sewerage	Irrigation
	78 (63.4%)	9 (7.3%)	4 (3.3%)	1 (0.8%)
	Industrial Facilities	Electrical Plants	Communications Networks	Others
	7 (5.7%)	16 (13.0%)	2 (1.6%)	6 (4.9%)
Classification rank (only for contractors)	Civil		Mechanical/Electrical/Chemical	
	14 (73.5%)		5 (26.5%)	
Respondent position	Top Management	Middle Management	Site Management	Supportive Management
	34 (27.6%)	44 (35.8%)	27 (22.0%)	18 (14.6%)
Respondent academic degree	PhD	MSc	BSc	Others
	27 (22.0%)	17 (13.8%)	76 (61.8%)	3 (2.4%)
Respondent specialization	Civil Engineers	Architects	Mechanical	Electrical
	68 (55.3%)	11 (8.9%)	18 (14.6%)	20 (16.3%)
	Communications	Highways	Chemical	Others
	1 (0.8%)	1 (0.8%)	0 (0.0%)	4 (3.3%)
Respondent years of experience in the construction industry	(6 – 10)	(11 – 15)	(16 – 20)	(> 20)
	22 (17.9%)	29 (23.6%)	39 (31.7%)	33 (26.8%)

The respondents' opinions about the possible benefits of implementing lean construction in Iraq are summarized in Table (3).

Table 3: Ranking of the possible benefits of lean construction

Factors	Respondents' Ranking						Mean	SD	RII%*	Ranking
	F/%	**1**	**2**	**3**	**4**	**5**				
Earlier completion time with greater certainty	F	8	6	59	31	19	3.3821	1.02045	67.642	3
	%	6.5	4.9	48	25.2	15.4				
Cost saving with higher profitability	F	7	7	60	30	19	3.3821	1.00426	67.642	2
	%	5.7	5.7	48.8	24.4	15.4				
Better quality assurance with greater reliability	F	4	13	56	25	25	3.439	1.03343	68.78	1
	%	3.3	10.6	45.5	20.3	20.3				
Higher productivity with less labour & inventory	F	5	10	60	32	16	3.3577	0.95067	67.154	4
	%	4.1	8.1	48.8	26	13				
Controlled environment with lower hazards	F	4	13	62	24	20	3.3496	0.98333	66.992	5
	%	3.3	10.6	50.4	19.5	16.3				
Sustainability enhancement with less energy	F	8	15	56	23	21	3.2764	1.0887	65.528	6
	%	6.5	12.2	45.5	18.7	17.1				

* RII: is the Relative Importance Index.

The respondents' opinions on the obstacles against lean construction adoption in Iraq were classified into exogenous and endogenous ones. Exogenous obstacles are those that are out of the institution control, while endogenous ones are within its intention. It can be noticed in Table (4), that the influences of the exogenous obstacles were higher than the endogenous ones.

Table 4: Ranking of the obstacles against lean construction adoption

Factors	Respondents' Ranking						Mean	SD	RII%*	Ranking
	F/%	1	2	3	4	5				
Exogenous Obstacles							**3.5535**	**0.76474**	**71.07**	**1**
Absence of government support	F	2	10	60	22	29	3.5366	0.99419	70.732	6
	%	1.6	8.1	48.8	17.9	23.6				
Lack of awareness and knowledge	F	4	9	43	30	37	3.7073	1.07682	74.146	2
	%	3.3	7.3	35	24.4	30.1				
Lack of a long-term vision.	F	4	6	52	31	30	3.626	1.0114	72.52	5
	%	3.3	4.9	42.3	25.2	24.4				
Fragmented nature of the industry	F	1	16	54	30	22	3.4553	0.96029	69.106	9
	%	0.8	13	43.9	24.4	17.9				
Many parties joined the project	F	2	10	49	32	30	3.6341	0.99398	72.682	4
	%	1.6	8.1	39.8	26	24.4				
Inefficient transportation and logistics	F	2	14	51	32	24	3.5041	0.98658	70.082	7
	%	1.6	11.4	41.5	26	19.5				
Hard to obtain technology and standardization	F	2	14	57	24	26	3.4715	1.00266	69.43	8
	%	1.6	11.4	46.3	19.5	21.1				
Initial and additional costs	F	2	13	60	28	20	3.4146	0.94024	68.292	11
	%	1.6	10.6	48.8	22.8	16.3				
Weak stakeholders' intention	F	8	11	59	21	24	3.3415	1.09267	66.83	12
	%	6.5	8.9	48	17.1	19.5				
Lack of engineers expertise and workers skills	F	3	10	40	25	45	3.8049	1.09887	76.098	1
	%	2.4	8.1	32.5	20.3	36.6				
Lack of transparency and integrity	F	6	11	41	22	43	3.6911	1.18134	73.822	3
	%	4.9	8.9	33.3	17.9	35				
Improper environmental conditions	F	5	17	45	29	27	3.4553	1.10329	69.106	10
	%	4.1	13.8	36.6	23.6	22				
Endogenous Obstacles							**3.2846**	**0.74029**	**65.692**	**2**
Lack of contractor/supplier involvement	F	11	12	59	26	15	3.1789	1.0638	63.578	10
	%	8.9	9.8	48	21.1	12.2				
Lack of prefabrication	F	1	20	67	20	15	3.2276	0.89455	64.552	7
	%	0.8	16.3	54.5	16.3	12.2				
Uncertainty in production process	F	3	18	69	17	16	3.2033	0.93177	64.066	9
	%	2.4	14.6	56.1	13.8	13				
Lack of identification and control of waste	F	1	21	58	25	18	3.3089	0.95067	66.178	3
	%	0.8	17.1	47.2	20.3	14.6				
High turnover of workforce	F	4	14	64	24	17	3.2927	0.95584	65.854	5
	%	3.3	11.4	52	19.5	13.8				
Lack of long-term relationship with suppliers	F	3	21	71	16	12	3.1057	0.88534	62.114	11
	%	2.4	17.1	57.7	13	9.8				
Multilayer subcontracting	F	6	10	66	17	24	3.3496	1.04005	66.992	2
	%	4.9	8.1	53.7	13.8	19.5				
Stress and pressure in deadlines	F	6	14	61	25	17	3.2683	1.0006	65.366	6
	%	4.9	11.4	49.6	20.3	13.8				
Poor team work culture	F	5	7	49	24	38	3.6748	1.09766	73.496	1
	%	4.1	5.7	39.8	19.5	30.9				
Absence of feedback	F	5	15	61	22	20	3.3008	1.01574	66.016	4
	%	4.1	12.2	49.6	17.9	16.3				
Losing some jobs due to work changes	F	3	21	62	20	17	3.2195	0.9712	64.39	8
	%	2.4	17.1	50.4	16.3	13.8				

* RII: is the Relative Importance Index.

The respondents' opinions on the readiness of the Iraqi construction industry to successfully adopt lean construction were investigated on two scales; national and institutional scales. The results are summarized in Table (5). The influences of the readiness success factors on national scale were found to be higher than the readiness success factors on institutional scale. This indicates that the major role in shifting to lean construction rests with the government and the construction sector leaders.

Table 5: Ranking of the readiness success factors

Factors	Respondents' Ranking						Mean	SD	RII%*	Ranking
	F/%	1	2	3	4	5				
On national scale							3.4869	0.83215	69.738	1
Government strategy and commitment	F	5	11	50	22	35	3.5772	1.11626	71.544	3
	%	4.1	8.9	40.7	17.9	28.5				
Demand and market conditions	F	0	19	54	23	27	3.4715	1.00266	69.43	6
	%	0	15.4	43.9	18.7	22				
Technology transfer	F	4	17	58	26	18	3.3008	0.99123	66.016	9
	%	3.3	13.8	47.2	21.1	14.6				
Awareness and knowledge	F	6	16	54	23	24	3.3496	1.08631	66.992	7
	%	4.9	13	43.9	18.7	19.5				
Expertise and skills	F	5	7	53	20	38	3.6423	1.10238	72.846	1
	%	4.1	5.7	43.1	16.3	30.9				
Design and process standardization	F	3	11	57	27	25	3.4878	0.99479	69.756	5
	%	2.4	8.9	46.3	22	20.3				
Information and communication technology	F	3	10	50	30	30	3.6016	1.02221	72.032	2
	%	2.4	8.1	40.7	24.4	24.4				
Research and development	F	2	14	62	19	26	3.4309	1.00067	68.618	8
	%	1.6	11.4	50.4	15.4	21.1				
Coordination/collaboration between parties	F	1	12	55	32	23	3.5203	0.93519	70.406	4
	%	0.8	9.8	44.7	26	18.7				
On institutional scale							3.4339	0.81093	68.678	2
Business and finance	F	6	11	51	26	29	3.4959	1.09675	69.918	4
	%	4.9	8.9	41.5	21.1	23.6				
Facilities and equipment	F	3	10	61	20	29	3.5041	1.01927	70.082	3
	%	2.4	8.1	49.6	16.3	23.6				
Design, manufacture & construction integration	F	3	11	48	27	34	3.6341	1.0579	72.682	1
	%	2.4	8.9	39	22	27.6				
Constructability and life-cycle engineering	F	0	12	56	25	30	3.5935	0.96528	71.87	2
	%	0	9.8	45.5	20.3	24.4				
Organization and leadership	F	1	19	53	22	28	3.4634	1.03459	69.268	6
	%	0.8	15.4	43.1	17.9	22.8				
Planning and control	F	3	13	56	26	25	3.4634	1.01054	69.268	5
	%	2.4	10.6	45.5	21.1	20.3				
Procurement and contracting strategy	F	4	16	66	19	18	3.252	0.97168	65.04	11
	%	3.3	13	53.7	15.4	14.6				
Supply and storage management	F	1	21	62	21	18	3.2764	0.94349	65.528	9
	%	0.8	17.1	50.4	17.1	14.6				
Cost and risk management	F	0	18	59	23	23	3.4146	0.95751	68.292	7
	%	0	14.6	48	18.7	18.7				
Transportation and logistics	F	4	17	64	19	19	3.2602	0.99042	65.204	10
	%	3.3	13.8	52	15.4	15.4				
Quality assurance and work environment	F	4	15	56	22	26	3.4146	1.05525	68.292	8
	%	3.3	12.2	45.5	17.9	21.1				

* RII: is the Relative Importance Index.

The respondents' opinions on the proposed actions needed to adopt lean construction in Iraq were classified into: knowledge and skills aspects, financial aspects, quality aspects, productivity aspects and management aspects and then investigated. It can be noticed in Table (6), that the influence of 'financial support' was the highest followed by 'productivity improvement', 'management enhancement', 'knowledge and skills leverage' and finally 'quality assurance'.

Table 6: Ranking of the proposed actions

Factors	Respondents' Ranking						Mean	SD	RII%*	Ranking
	F/%	1	2	3	4	5				
Knowledge/skills leverage:							**3.4439**	**0.87798**	**68.878**	**4**
Academic education	F	4	14	55	28	22	3.4065	1.01495	68.13	3
	%	3.3	11.4	44.7	22.8	17.9				
Consultants' development programs	F	5	12	47	29	30	3.5447	1.08833	70.894	1
	%	4.1	9.8	38.2	23.6	24.4				
Manufacturers' & Contractors' dev. programs	F	6	14	53	28	22	3.374	1.05891	67.48	4
	%	4.9	11.4	43.1	22.8	17.9				
Labour training programs	F	1	12	56	28	26	3.5366	0.96064	70.732	2
	%	0.8	9.8	45.5	22.8	21.1				
Regulations, codes, standards and certification	F	4	15	58	25	21	3.3577	1.00922	67.154	5
	%	3.3	12.2	47.2	20.3	17.1				
Financial support:							**3.5984**	**0.79403**	**71.968**	**1**
Demand continuity and stability	F	5	13	56	21	28	3.439	1.07997	68.78	5
	%	4.1	10.6	45.5	17.1	22.8				
Affordable loans	F	1	21	39	39	23	3.5041	1.0112	70.082	4
	%	0.8	17.1	31.7	31.7	18.7				
Tax exemption and levy reduction	F	5	14	46	27	31	3.5285	1.11123	70.57	3
	%	4.1	11.4	37.4	22	25.2				
Business and marketing	F	2	5	53	39	24	3.6341	0.89871	72.682	2
	%	1.6	4.1	43.1	31.7	19.5				
Non-delayed payment	F	3	5	41	28	46	3.8862	1.04178	77.724	1
	%	2.4	4.1	33.3	22.8	37.4				
Quality assurance:							**3.4016**	**0.8394**	**68.032**	**5**
Product, process and people certification	F	2	14	64	22	21	3.374	0.95298	67.48	4
	%	1.6	11.4	52	17.9	17.1				
Design, manufacture & construction integration	F	4	12	51	20	36	3.5854	1.10829	71.708	1
	%	3.3	9.8	41.5	16.3	29.3				
Design and processes standardization	F	3	15	54	30	21	3.4146	0.99116	68.292	2
	%	2.4	12.2	43.9	24.4	17.1				
Causal analysis and technical solutions	F	5	12	52	37	17	3.3984	0.9813	67.968	3
	%	4.1	9.8	42.3	30.1	13.8				
Environmentally friendly life cycle engineering	F	5	17	60	26	15	3.2358	0.97578	64.716	5
	%	4.1	13.8	48.8	21.1	12.2				
Productivity improvement:							**3.5024**	**0.86966**	**70.048**	**2**
Mechanization	F	9	4	49	26	35	3.6016	1.15048	72.032	2
	%	7.3	3.3	39.8	21.1	28.5				
Training	F	0	15	50	23	35	3.6341	1.02644	72.682	1
	%	0	12.2	40.7	18.7	28.5				
Controlled environment	F	2	12	60	28	21	3.439	0.94215	68.78	3
	%	1.6	9.8	48.8	22.8	17.1				
Health and safety measures	F	1	19	59	23	21	3.3577	0.96776	67.154	5
	%	0.8	15.4	48	18.7	17.1				
Information and communication technology	F	5	7	58	30	23	3.4797	0.99465	69.594	4
	%	4.1	5.7	47.2	24.4	18.7				
Management enhancement:							**3.4894**	**0.8945**	**69.788**	**3**
Change strategy	F	8	12	50	29	24	3.3984	1.10691	67.968	4
	%	6.5	9.8	40.7	23.6	19.5				
Extensive planning and control	F	2	15	56	24	26	3.4634	1.01054	69.268	3
	%	1.6	12.2	45.5	19.5	21.1				
Organization and leadership	F	7	9	51	23	33	3.5366	1.13291	70.732	2
	%	5.7	7.3	41.5	18.7	26.8				
Collaboration and coordination	F	0	13	48	28	34	3.6748	0.99586	73.496	1
	%	0	10.6	39	22.8	27.6				

Transportation, logistics & supply chain management.	F	4	10	63	28	18	3.374	0.94434	67.48	5
	%	3.3	8.1	51.2	22.8	14.6				

Reliability and Validity of Results

The results of Cronbach's alpha test are shown in Table (7) in which it can be noticed that the internal consistency of factors as a whole is (98.5%) which means high degree of consistency.

Table 7: Reliability test results of the respondents evaluation of factors

Sections	Number of factors	Cronbach's Alpha
Lean Construction Benefits	6	0.889
Exogenous Obstacles	12	0.923
Endogenous Obstacles	11	0.923
Readiness on national scale	9	0.934
Readiness on company scale	11	0.945
Knowledge and skills leverage	5	0.908
Financial support	5	0.828
Quality assurance	5	0.893
Productivity improvement	5	0.907
Management enhancement	5	0.912
All	74	0.985

Furthermore, one-way variance analysis was conducted between and within groups of the questionnaire results, to define any significant variances amongst the views of respondents which were classified according to their general information. The mean values, F statistics, and P-values were measured. A sample of the ANOVA tests results is shown in Table (8).

Table 8: ANOVA test for respondents' organization field of practice

		Sum of Squares	df	Mean Square	F	Sig.
Lean Construction Benefits	Between Groups	3.581	7	.512	.763	.619
	Within Groups	77.105	115	.670		
	Total	80.686	122			
Exogenous Obstacles	Between Groups	1.452	7	.207	.341	.933
	Within Groups	69.897	115	.608		
	Total	71.349	122			
Endogenous Obstacles	Between Groups	2.514	7	.359	.642	.720
	Within Groups	64.345	115	.560		
	Total	66.859	122			
Readiness on national scale	Between Groups	4.849	7	.693	1.000	.435
	Within Groups	79.633	115	.692		
	Total	84.482	122			
Readiness on company scale	Between Groups	3.610	7	.516	.774	.610
	Within Groups	76.618	115	.666		
	Total	80.228	122			
Knowledge and skills leverage	Between Groups	4.771	7	.682	.878	.526
	Within Groups	89.272	115	.776		
	Total	94.043	122			

Financial support	Between Groups	4.363	7	.623	.988	.444
	Within Groups	72.557	115	.631		
	Total	76.920	122			
Quality assurance	Between Groups	4.919	7	.703	.997	.437
	Within Groups	81.041	115	.705		
	Total	85.960	122			
Productivity improvement	Between Groups	4.320	7	.617	.807	.583
	Within Groups	87.949	115	.765		
	Total	92.269	122			
Management enhancement	Between Groups	4.091	7	.584	.719	.656
	Within Groups	93.525	115	.813		
	Total	97.616	122			

Moreover, normality test was carried out using Kolmogorov-Smirnov and Shapiro-Wilk measures of normality. The results are shown in Table (9).

Table 9: Normality tests results

Questionnaire Sections	Kolmogorov-Smirnov*			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Lean Construction Benefits	.012	123	.071	.069	123	.056
Exogenous Obstacles	.012	123	.069	.081	123	.076
Endogenous Obstacles	.030	123	.054	.076	123	.030
Readiness on national scale	.029	123	.017	.074	123	.018
Readiness on company scale	.035	123	.140	.072	123	.011
Knowledge and skills leverage	.032	123	.130	.072	123	.012
Financial support	.008	123	.071	.072	123	.010
Quality assurance	.031	123	.120	.069	123	.006
Productivity improvement	.011	123	.101	.065	123	.003
Management enhancement	.013	123	.081	.060	123	.001
Type of projects suitable for LC	.019	123	.090	.077	123	.031
* Lilliefors Significance Correction.						

The Interviews Results:

The interviews were conducted with (12) out of (123) questionnaire respondents and found to be consistant and eough. They included (3) clients, (3) consultants, (3) contractors, (2) suppliers and (1) manufacturer. There were (8) from the public sector and (4) from the privet sector, (3) holding PhD, (4) MSc and (5) BSc, (10) civil and (2) EMP engineers having (10-25) years of experience. There jobs covered top, middle, site and supportive management. The interviews clarified the sources of the few different opinions gained through the questionnaire to be due to: lack of proper understanding of lean construction, imperfect governmental regulations, contractors-suppliers relations, desperateness, lack of knowledge of modern construction technologies, lack of knowledge in modern ICT applications in construction projects, and lack of knowledge in sustainability aspects.

Discussion:

Concerning the benefits, it can be noticed that the respondents allocated almost the same importance for all potential benefits. This can be attributed to that the Iraqi construction industry is in need of all potential benefits that lean construction can provide. Value maximization as a major objective of lean construction stands for ranking the potential benefit of 'better quality assurance with greater reliability' at first. Using standardization, prefabrication and modern construction techniques in lean construction is another reason for that. Time and cost saving and west mitigation are obvious basic drivers of lean construction. Productivity is also expected to be higher because communicating, collaborating, and a safe and effective work environment are all emphasized in lean construction. Lean construction lowers downtime by removing inefficiencies in the process of obtaining supplies, equipment, and information. Furthermore, lean construction is expected to reduce risks and enhance safety because of better monitoring and control of activities.

Among the exogenous obstacles, it can be noticed that the 'lack of engineers expertise and workers skills' had the highest influence followed by 'lack of awareness and knowledge'. This ranking looks realistic because the adoption of any new technology or method requires, first of all, appropriate experience and skills supported by adequate knowledge and awareness. On the other hand, corruption, bureaucracy, inflation and prices fluctuation are out of the construction parties' control.

Among the endogenous obstacles, it can be noticed that 'poor team work culture' had the highest influence followed by 'multilayer subcontracting'. This ranking also looks realistic because teamwork by all parties is the backbone of lean construction and the fact of multilayer subcontracting makes it more essential. Feedback and other factors related to it, such as waste identification and meeting deadlines, seem to have the same importance. Factors related to construction techniques like prefabrication and job changes seem also to have the same effect. In general, all endogenous factors seem to have very close effects.

Among the readiness success factors on national scale, it can be noticed that 'expertise and skills' were confirmed to have the highest influence followed by 'information and communication technology'. It can be clearly noticed that the ranking of readiness success factors on national scale conform to the ranking of obstacles to be treated.

Among the readiness success factors on institutional scale, it can be noticed that the 'integration of design, manufacture and construction activities' had the highest influence followed by 'constructability and life-cycle engineering'. More emphasis was made to engineering-related factors (e.g. design, constructability and equipment) than management-related factors (e.g. business, planning, organization …) and logistics-related factors (e.g. storage, transportation and procurement).

Because all actions need to be financed, it can be noticed that more emphasis was made to financial actions like timely payment, marketing, tax reduction, affording loans and demand stability. All other factors received almost the same level of attention. This result necessitated supporting the questionnaire with direct interviews to dig deeply.

Concerning productivity enhancement actions, 'training' and 'mechanization' received higher attention than work environment, communication and safety, a matter that emphasis the importance of skills and technology as stressed earlier in the readiness success factors.

Regarding management actions, 'collaboration' received higher attention than organization, planning, strategy and transportation, this conform to the need of team-work emphasized earlier in the readiness success factors.

The knowledge and skills leverage actions including; development programs for each party, education, training and codes, showed some contradictions. This is attributed to that each party blames the other parties. This result also necessitated supporting the questionnaire with direct interviews to dig deeply.

Finally quality assurance actions received the lowest ranking including; integration, standardization, causal analysis, certification and life-cycle engineering. This might be due to the need to satisfy first the other aspects of finance, productivity, management and knowledge in order to satisfy quality assurance.

In all ANOVA tests results, it was noticed that the P-value (Sig.) is higher than (5%) for all factors in all cases except very few ones, which means there are no differences between answers in the vast majority of the results. The reason of this limited variation is due to the conflict of interest between the construction industry stakeholders (including different construction project parties). Each evaluated the factors based on his own point of interest.

Concerning the normality test, it can be noticed that the significance value is higher than (5%) in most of the cases which means that all results are normally distributed except in one case in Kolmogorov-Smirnov test and few cases in Shapiro-Wilk test. This is also due to the conflict of interest between the parties.

Conclusions:

1. Performing precise planning and design is crucial to implement lean construction, for it needs much more scrutinizing of all activities than other approaches. As much as planning and design are precise, the project success opportunities are higher in meeting time, cost and quality targets. For instance, how simple, clear, complete, practical, flexible, economic and eco-friendly is the design, bill of quantities, cost estimating, time scheduling, cash-flow forecasting, resources allocation and feasibility study. Modern techniques like building information modeling (BIM) can be of great aid in this sense. Therefore, enough care should be taken in assigning the consultancy and design team.
2. The procurement phase in lean construction is much more important than in traditional construction because of the higher number of deals need to be timely accomplished. When there are some mistakes in any deal, all other related deals will be affected. Therefore, enough time and care should be paid to the procurement process in order to minimize the risk. Care should also be taken in deciding on the type of contract and terms of payment among different procurement methods with different roles of the main parties as well as different payment strategies.
3. The execution stage of any construction project represents the real challenge of lean construction implementation. Therefore, well-trained staffs with enough knowledge and skills need to be provided. Standardization, off-site manufacturing, prefabrication, modern technology, team spirit, and waste prevention of all kinds are vital. An effective monitoring and follow-up technique is required. The Last Scheme System, Last Planner, and Lean Project Delivery System are advisable work management techniques for program coordination, product delivery, continuous monitoring and plans updating.
4. The industry stakeholders should provide enough administrative and financial support to assure the project success in meeting specified time, cost and quality. This might include ensuring; financial liquidity, qualified staff, integration of design, manufacturing and construction, quality assurance through institutional and personal certification, simplifying contract conditions and bidding procedures, timely delivery of all needed resources, prompt response to resolve work issues and active coordination with other parties.
5. The government has a crucial role in adopting new strategies for the constructing industry. It is responsible for relevant legislations and infrastructure management. It has the power and tools to reorganize the market by adopting encouraging policies for tax exemption, banking facilities, bonds and loans, and stable prices and rates of exchange, ensuring the continuity of supply and demand, human resources development and technology transfer.
6. Vocational centers, manufacturers, contractors, professional organizations and labour unions should provide for organizing continual training courses on modern methods and techniques. Academic institutions might have a role in education and research too. Education and training should include courses and seminars for consultants, constructors and technicians, to enhance the culture of lean construction, technology transfer, design and manufacturing standardization, causal analysis, sustainability and life cycle analysis.

7. It is obvious that modern technology facilitates construction works; meanwhile, the challenge is how to transfer modern technology and adopt it locally. Using contemporary materials, equipment and techniques in lean construction, especially prefabrication, can provide for better quality and productivity, less health and safety hazards, more sustainable and eco-friendly products using renewable energy, and less energy consumption. In addition of using modern hardware or software for information and communication technology.

References

1. Abdullah, S., Abdul-Razak, A., Abubakar, A.-H. and Mohammad, I. S. (2009). Towards Producing Best Practice in the Malaysian Construction Industry: The Barriers in Implementing the Lean Construction Approach. International Conference on Construction Industry 2 (ICCI2). Padang, Indonesia.

2. Akinradewo, O., Oke, A. E., Aigbavboa C. and Ndalamba, M. (2018). Benefits of Adopting Lean Construction Technique in the South African Construction Industry. Proceedings of the International Conference on Industrial Engineering and Operations Management. Pretoria. Johannesburg, South Africa, October 29 - November 1, 2018.

3. Al Balkhy, W., Sweis, R. and Lafhaj, Z. (2021). Barriers to Adopting Lean Construction in the Construction Industry - The Case of Jordan. Buildings, Vol. 11, 222. pp. 1-17.

4. Albanna, R. M. (2019). Developing a tool to assess and enhance the workers' understanding of lean concepts in construction. Phd Dissertation. American University of Beirut, Lebanon.

5. Alinaitwe, H. M. (2009). Prioritizing Lean Construction Barriers in Uganda's Construction Industry. Journal of Construction in Developing Countries, 14(1). pp 15-30.

6. Amunzu, I. C. (2020). A Qualitative Case Study of Construction Managers' Understanding of Lean Thinking. PhD Dissertation. Grand Canyon University. Phoenix, Arizona, USA.

7. Ansah, R. H., Sorooshian, S., Mustafa, S. B., and Duvvuru, G. (2016). Lean Construction Tools. In Proceedings of the International Conference on Industrial Engineering and Operations Management. Detroit, Michigan, USA.

8. Aslam, M., Gao, Z. and Smith G. (2020). Exploring Factors for Implementing Lean Construction for Rapid Initial Successes in Construction. Journal of Cleaner Production. 277(3). 123295.

9. Ballard, G. and Tommelein, I. (2016). Current Process Benchmark for the Last Planner System. Lean Construction Journal. 57-89.

10. Blokdyk, G. (2019). Lean Production: A Complete Guide - 2019 Edition. 5STARCooks.

11. Dede G. (2018). Lean and BIM Based Waste Management. Masters Thesis. Mimar Sinan Fine Arts University. Turkey.

12. Demirkesen, S. (2021). From Lean Manufacturing to Lean Construction: How Principles, Tools, and Techniques Evolved. Open Access Peer-Reviewed Chapter. From the Edited Volume Lean Manufacturing. Chapter Metrics Overview. DOI: 10.5772/İntechopen.96191.

13. Demirkesen, S. and Bayhan, H. G. (2020). A Lean Implementation Success Model for the Construction Industry. Engineering Management Journal. 32(3). PP. 219-239.

14. Enshassi, M. A., Mohamed, S., Mustafa, Z. A. and Mayer, P. E. (2007). Factors Affecting Labor Productivity in Building Project in Gaza Strip, Journal of Civil Engineering and Management, Vol. 13, No. 4, Pp. 245-254.

15. Enshassi, A., Saleh, N. and Mohamed, S. (2019). Application Level of Lean Construction Techniques in Reducing Accidents in Construction Projects. Journal of Financial Management of Property and Construction.

16. Forbes, L. H. and Ahmed, S. M. (2020). Modern Construction: Lean Project Delivery and Integrated Practices. 2nd Edition. Routledge. Taylor & Francis.

17. Gao, S. and Low, S. P. (2014). The Last Planner System in China's Construction Industry - A SWOT Analysis on Implementation. International Journal of Project Management, 32(7), 1260-1272.

18. Gunduz, M. and AbuHassan, M. H. A. (2017). Mapping the Industrial Perception of Delay Data through Importance Rating. Arabian Journal for Science and Engineering, Vol. 42, Issue 9, pp. 3799-3808.

19. Gupta, S., Ahmadi, M. A. and Kumar, L. (2020). Identification of the Barriers of Lean Construction Implementation in Construction Projects - A Review. International Research Journal of Engineering and Technology (IRJET). Vol. 8, Issue 3.

20. Hasan, M. F. (2015). Developing a Prediction Model for Public School Building Projects Completion Time at Contract Assignment Stage. MSc thesis, University of Technology, Building and Construction Engineering Department, Iraq.

21. Jorgensen, B. and Emmitt, S. (2008). Lost in Transition: The Transfer of Lean Manufacturing to Construction. Engineering, Construction and Architectural Management. 15 (4), pp. 383-398.

22. Khah, F., Rybkowski, Z., Pentecost, R., Smith, J. P. and Muir, R. (2019). Development and testing of an Innovative Architectural Programming Simulation as a Precursor to Target Value Design. 27th Annual Conference of the International Group for Lean Construction (IGLC), 3-5 July 2019, Dublin, Ireland.

23. Koohestani, K., Poshdar, M., and Gonzalez, V. A. (2020). Finding the Way to Success in Implementing Lean Construction in an Unfavourable Context. In: Tommelein, I. D. and Daniel, E. (eds.). Proc. 28th Annual Conference of the International Group for Lean Construction (IGLC28), Berkeley, California, USA.

24. Le Gratiet, G. C. (2017). Implementation of Lean Construction Tools on an On-Going Project: A Case Study on a Tower Project. Masters Thesis, Department of Mechanical and Manufacturing Engineering, Aalborg University, Denmark.

25. Modi, D. B. and Thakkar, H. (2014). Lean Thinking: Reduction of Waste, Lead Time, Cost through Lean Manufacturing Tools and Technique. International Journal of Emerging Technology and Advanced Engineering, 4(3), pp. 334-339.

26. Mohammed, S. R. and Jasim, A. J. (2018). Using Agile Construction Management Principles for Reducing Delay in Iraqi Construction Industry. Association of Arab Universities Journal of Engineering Sciences. Vol. 25, No. 5.

27. Mossman, A. (2009). Why isn't the UK construction industry going lean with gusto? Lean construction journal, 5(1): 24-36.

28. Mustonen, I. (2018). Implementation of Lean Construction Tools and Their Contribution to Site Management Process. MSc Thesis. Tampere University of Technology.

29. Olatunji, J. (2008). Lean-in-Nigerian Construction: State, Barriers, Strategies and "Goto-gemba" Approach, Proceedings 16th Annual Conference of the International Group for Lean Construction. Manchester, UK.

30. Ozdemir, M. (2010). A Probabilistic Schedule Delay Analysis in Construction Projects by using Fuzzy Logic in Corporate with Relative Importance Index (RII) Method. MSc Thesis, University of Middle East Technical, The Graduate School of Natural and Applied Sciences, Turkey.

31. Sarhan, J. G., Xia, B., Fawzia, S. and Karim, A. (2017). Lean Construction Implementation in the Saudi Arabian Construction Industry. Construction Economics and Building, 17:1, 46-69.

32. Singh, S. and Kumar, K. (2020). A Study of Lean Construction and Visual Management Tools through Cluster Analysis. Ain Shams Engineering Journal. Architectural Engineering. Vol. 12. Issue 1. Pp. 1153-1162.

33. Small, E. P., Al-Hamouri, K. and Al-Hamouri, H. (2017). Examination of Opportunities for Integration of Lean Principles in Construction in Dubai. Procedia Engineering, Creative Construction Conference 2017, CCC 2017, 19-22 June 2017, Primosten, Croatia, Vol. 196, p. 616–621.

34. Tommelein, I., and Demirkesen, S. (2018). Mistakeproofing the Design of Construction Processes Using Inventive Problem Solving (TRIZ). University of California, Berkeley. Final Report for CPWR Small Study No. 16-3-PS.

35. Vilasini, N., Neitzert, T. R. and Rotimi, J. O. (2011). Correlation between Construction Procurement Methods and Lean Principles. International Journal of Construction Management, 11(4): 65-78.

36. Watfa, M. and Sawalha, M. (2021). Critical Success Factors for Lean Construction: An Empirical Study in the UAE. Lean Construction Journal. Issue 2021. pp. 01-17.

37. Womack, J. (2013). Gemba Walks. Expanded 2nd Edition. Lean Enterprise Institute.
38. Womack, J. P. and Jones, D. T. (2003). Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Second Edition. New York, NY: Free Press, Simon & Schuster Inc.
39. Yuan, Z. Zhang, Z. Ni, G. Chen, C. Wang, W. and Hong, J. (2020). Cause Analysis of Hindering On-Site Lean Construction for Prefabricated Buildings and Corresponding Organizational Capability Evaluation", Advances in Civil Engineering, Vol. 2020, Article ID 8876102, 16 pages.
40. Yusof, I. H. M. (2018). Development of Lean Design Process for Building Construction Projects. PhD Thesis. Department of Civil Engineering. University of Birmingham. UK.