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Implementing Lean Construction: A Literature Study of Barriers, Enablers, and Implications

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Abstract: The challenges of adopting and implementing lean construction (LC) have led to substantial but isolated research studies concerning the relevant barriers, enablers, and implications, which lack a comprehensive approach and analytical as well as conceptual perspectives. Hence, this study aims to fill the mentioned knowledge gap by identifying the barriers, enablers, and implications of implementing lean construction and exploring their relatedness. A systematic literature review was carried out through which 230 located studies were analyzed using thematic and content analysis methods to realize the objectives of this study. The findings suggest that the lack of awareness and understanding of LC, resistance to change, and a lack of support and commitment from top management are the top three barriers toward LC adoption and implementation, which can be overcome using the identified enablers, among which the top three ones were developing lean culture, application of lean principles tools and techniques, and top management support and commitment. Moreover, the results present a model which portrays the relatedness between the discovered barriers, enablers, and implications of applying lean construction. The findings can be insightful for the research community and project practitioners in their efforts for facilitating the adoption and implementation of lean construction.

Keywords: collaborative construction; construction management; lean construction

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1. Introduction

The construction industry, in the big picture, has been, for a long time, an example of a wasteful sector with high fragmentation and low productivity. This outcome has been mainly attributed to the disadvantages of construction projects with traditional delivery models (e.g., design-bid-build), including late involvement of the contractor in design and planning, unreliable design and planning, rework, an unfair share of risk–reward, mistrust, and unaligned interests of project stakeholders [1–6]. As a response to these disadvantages and destructive features, lean construction emerged in the 1990s with a simple but meaningful ideal, which was understanding the customer's needs and delivering a fit for purpose product/service with high value and low waste. Lean construction has been defined as the adoption and application of principles and techniques related to lean manufacturing in the context of construction to realize the mentioned ideal [7–10].

According to Dave and Sacks [11], the foundation of lean construction was formed through the proposition of the transformation–flow–value (TFV) theory by Koskela [12] and the development of the lean project delivery system by Ballard [13]. TFV refers to the conceptualization of the production process through three key elements, which are transformation (production of inputs into outputs), flow (movement that is reliable and continuous), and value (what the customer needs and pays for it) [14]. Lean project delivery system, according to Ballard and Howell [15], links five phases (project definition, lean design, lean supply, lean assembly, and use) of the lifecycle. The lean project delivery system addresses construction as production, and reliable production management is of prime importance in lean project delivery systems, which is realized by utilizing the last planner system [15]. The development of the last planner system was undertaken as a reaction to the critical path method (CPM) approach, which has been mostly employed for planning and control in construction projects with traditional delivery models [16]. According to Ballard [16], the last planner system has five components which are master scheduling (SHOULD be done), phase scheduling (SHOULD be done), look ahead planning (CAN be done), daily/weekly work planning (CAN be done), and learning (DID).

As can be understood, there are significant differences between traditional and lean construction. These differences in the holistic view can be explained by mentioning those constructive and key features which lean construction has but traditional construction lacks. These features are production-oriented project delivery, pull planning (the last planner system), unanimous decision-making, joint design of product and process, using contingency reserves for reducing system variability (not local optimization), and aligned interests of stakeholders (through the fair share of risk–reward and joint design and planning) [15,17,18]. Accordingly, it is obvious that the adoption and application of lean construction can be very useful and effective for overcoming the issues of traditional construction [19–21]. However, it is also obvious that adopting and implementing lean construction has been very challenging in many countries. In this regard, extensive research has been conducted in the last three decades concerning enablers and barriers (e.g., [22–26]) as well as the implications of implementing lean construction (e.g., [27–30]).

However, there are very few, if any, studies addressing LC implementation in a systematic manner by identifying the barriers, enablers, and implications of its implementation and revealing the relatedness between them. Thus, this study aims to fill the mentioned knowledge gap through answering the following research questions:

RQ1. What are the barriers and enablers for implementing lean construction?

RQ2. What are the implications of adopting and implementing lean construction?

RQ3. What are the connections between the barriers, enablers, and implications of implementing lean construction?

The resultant paper is structured into six sections. The first one introduces the problem and the objectives of this study. The next section includes the theoretical background, which is followed by an explanation of the methodology. Then, the obtained results are presented and discussed. Finally, the conclusions, drawn from the findings, are stated.

2. Theoretical Background

The research community has been active during the last three decades in undertaking research on lean construction. Analyzing the literature shows that a few research themes can be mentioned regarding lean construction research, including the integration of lean construction with BIM and sustainability (e.g., [31–37]), lean design and planning (e.g., [38–43]), waste identification and elimination (e.g., [44–47]), lean construction education (e.g., [48–50]), and enablers and barriers of adopting and applying LC (e.g., [51–54]) as well as the implications of implementing lean construction (e.g., [20,30,55–57]). Among the mentioned themes, the barriers, enablers, and implications of LC application fit the scope of this study and are discussed in the following.

Exploring the barriers of adopting and implementing lean construction, as a topic, has received considerable attention from the research community. These studies have been conducted in various geographical locations. For instance, the studies conducted in Hong Kong and the USA in 2012 found that a lack of awareness and understanding of LC, a lack of effective communication between all project participants, the size of the construction project, and a lack of sustainable practices hinder the adoption and implementation of lean construction [58,59]. Another study carried out by Khaba and Bhar [26] identified more than 10 barriers toward implementing lean construction, of which insufficient support from the government (providing the required policies, codes, and regulations), lack of performance measurement systems, poor understanding of customer needs and poor customer focus, project subcontracting, financial constraints, and cultural differences can be mentioned as examples. Moreover, the study undertaken by Bajjou and Chafi [60] resulted in the identification of three important barriers which were a lack of awareness, lack of competence (both at managerial and employee level), and financial constraints. These efforts were followed by more research studies between 2019 and 2021 in which important barriers were explored, including resistance to change (management and employees), a lack of involvement and transparency among stakeholders, a lack of planning for quality, implementation costs and time, limited use of off-site construction techniques and prefabrication, and traditional design and delivery approach [61–69].

Identifying enablers of adopting and implementing lean construction has been also addressed by the research community in a considerable manner. In addition, similar studies addressing barriers and previous research on the enablers of LC implementation have been undertaken in various countries. For instance, the study conducted by Alarcón et al. [51] in Chile found out that lean education, training, and research together with continuous improvements in process and product development and collaborative working relationships between project parties are important enablers for implementing lean construction. In addition, research carried out by Yahya and Mohamad [70] in Malaysia discovered that knowledge creation and management, developing LC-oriented performance measurement frameworks, and promoting a culture of teamwork during construction projects play a very important role in enabling the implementation of lean construction. These efforts were then followed by other studies which were conducted in the USA, Brazil, and the UK in 2017, resulting in the identification of enablers such as developing lean culture through promoting lean education, training and research, investor/client requirements, and bottom-up strategy [9,71,72]. This trend continued in the following years (2018–2021) with studies which were conducted in various regions, including China, India, Norway, South Africa, Saudi Arabia, New Zealand, Brazil, the USA, Turkey, and Iran. These research efforts revealed the importance of enablers, such as top management support and commitment, building trust, pull production, collaborative practices, promoting a culture of teamwork during construction projects, competent human resources, and support of government and regulatory bodies [53,54,73–84].

The third topic here to discuss in relation to the enablers and barriers is the implications of adopting and implementing lean construction. This topic has also been very interesting among different scholars in the research community, and there is great research-based knowledge concerning the benefits of applying lean construction. A similarity between these three topics (enablers, barriers, and implications) is the variety of the contexts in which they have been addressed. Here, previous studies addressing the implications of applying lean construction are explained in three different time spans in a chronological manner. The first time span is 2005–2010 in which five studies were conducted in the UK (2006), the USA (2009, 2010), Taiwan (2010), and Sweden (2010), resulting in the identification of implications such as decreased inventory, waste reduction, the establishment of collaborative climate, and time as well as cost reduction [29,84–87]. The second time span is 2011–2015 in which three studies can be exemplified which were carried out in the UK (2012) and Iran (2014) and found that implementing lean construction led to increased labor productivity, increased process efficiency, and increased productivity (at task and project levels) [55,88,89]. The last time span is 2016–2022, which contains the majority of the conducted studies regarding this topic. In this period, 15 studies were conducted in 14 different countries (Turkey, Saudi Arabia, Brazil, France, Lebanon, Norway, Pakistan, India, the UK, Morocco, Canada, Malaysia, Denmark, and Russia). The findings of these studies were not only in line with the results of the previous research but also included explorations of the additional implications of applying lean construction, including better operational performance, quality improvement, and stakeholder satisfaction [19,21,27,28,30,56,57,90–98].

To sum up, it can be stated that analyzing the literature shows an obvious research gap concerning a comprehensive view over the barriers, enablers, and implications of adopting and applying lean construction. To fill this knowledge gap, this study aims to answer the research questions which were mentioned earlier in the introduction section.

3. Methodology

3.1. Research Design

In this study, systematic literature review was employed to explore the barriers, enablers, and implications of adopting and implementing lean construction. To do so, the relevant studies were located from Scopus database. This was followed by abstract review of the located studies, resulting in the exclusion of irrelevant ones and repetitions. Then, full-text review of the relevant studies was completed, and the thematic analysis method [99] was utilized for analyzing the extracted research data. Figure 1 shows the process of data collection and analysis in this research. Further details are explained in the following sub-sections.

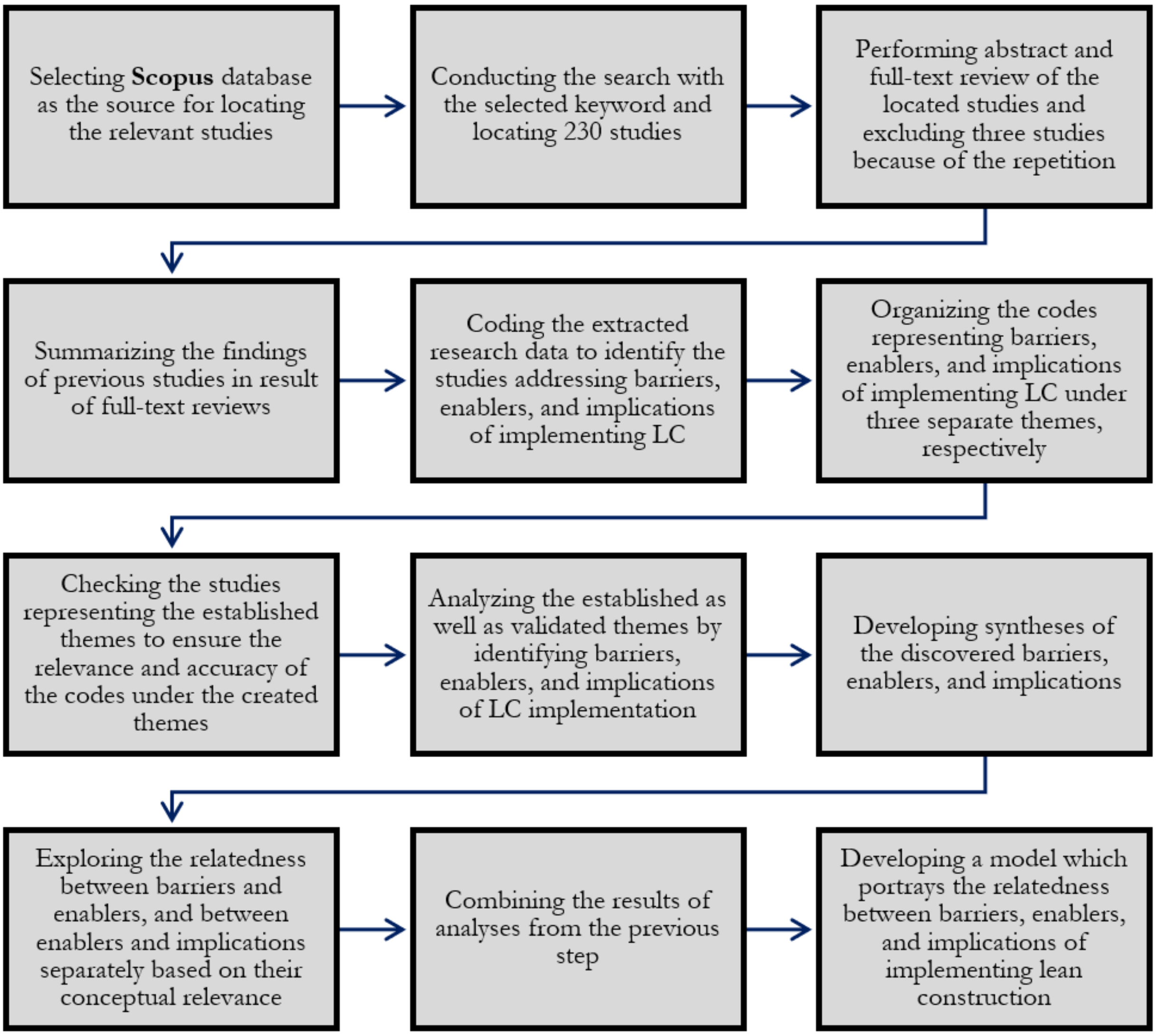

Figure 1. Research process.

3.2. Keyword Selection

According to the purpose of this study, the term "Lean Construction" was selected as the keywords for locating the relevant studies from Scopus database. Scopus database was chosen as the main database for locating the relevant studies because it contains most of the relevant and well-known journals on lean construction and construction management. The decision for using "Lean Construction" as the keywords can be justified according to this study's focus, which was on the previous research addressing enablers, barriers, and implications of implementing lean construction.

3.3. Descriptive Statistics

The performed search resulted in locating 230 accessible studies by authors, of which 55% (127) were journal articles, and 44% (103) were conference proceedings. In total, 3 out of 230 located studies were excluded due to the repetition. This was followed by reviewing and analyzing the full text of the remaining 227 studies. In this study, no specific time span was applied for locating the relevant studies in order to make sure that the search was sufficiently comprehensive. More than 85% of the 227 analyzed studies were published between 2011 and 2022. This is usually important due to the higher relevance of recent publications. Figure 2 shows context of the analyzed studies in this research, addressing enablers, barriers, and implications of implementing lean construction.

No	Context of studies addressing the LC implementation **barriers**	Year	Reference
1	The USA	2012	Koranda et al., 2012
2	Hong Kong	2012	Li et al., 2012
3	India	2017	Khaba and Bhar, 2017
4	Morocco	2018	Bajjou and Chafi, 2018
5	Germany	2019	Demirkesen et al., 2019
6	Australia	2019	Innella et al., 2019
7	Bangladesh	2020	Ahmed and Sobuz, 2020
8	Literature	2020	Al balkhy and Sweis, 2020
9	Literature	2020	Mano et al., 2020
10	China	2020	Yuan et al., 2020
11	Sweden	2020	Ivina and Olsson, 2020
12	Bangladesh	2021	Ahmed et al., 2021
13	Peru	2021	Orosco and Rondinel, 2021
14	Palestine	2021	Enshassi et al., 2021
15	Jordan	2021	Al Balkhy et al., 2021
16	China	2021	Li and Hao, 2021
17	India	2022	Thomas and Khanduja, 2022

No	Context of studies addressing the LC implementation **enablers**	Year	Reference
1	Chile	2008	Alarcón et al., 2008
2	Malaysia	2011	Yahya and Mohamad, 2011
3	The USA	2017	Salazar et al., 2017
4	Brazil	2017	Zanotti et al., 2017
5	The UK	2017	Tezel et al., 2017
6	Norway	2018	Torp et al., 2018
7	Literature	2018	Ankomah et al., 2018
8	India	2018	Karanjawala and Baretto, 2018
9	China	2018	Chen et al., 2018
10	South Africa	2019	Maradzano et al., 2019
11	New Zealand	2019	Poshdar et al., 2019
12	China	2019	Wu et al., 2019
13	Saudi Arabia	2019	Sarhan et al., 2019
14	Literature	2019	Darabseh, 2019
15	Brazil	2020	Valente et al., 2020
16	Türkiye	2020	Demirkesen and Bayhan, 2020
17	Iran	2020	Koohestani et al., 2020
18	The USA	2020	Al Heet et al., 2020
19	The USA	2020	Uddin, 2020
20	Literature	2022	Habibi Rad et al., 2022

No	Context of studies addressing the LC implementation **implications**	Year	Reference
1	The UK	2006	Fearne and Fowler, 2006
2	The USA	2009	Nahmens, 2009
3	Taiwan	2010	Ko, 2010
4	Sweden	2010	Eriksson, 2010
5	The USA	2010	Garrett and Lee, 2010
6	The UK	2012	Sage et al., 2012
7	The UK	2012	Pasquire, 2012
8	Iran	2014	Abbasian-Hosseini et al., 2014
9	France	2017	Dakhli et al., 2017
10	Türkiye	2017	Erol et al., 2017
11	Saudi Arabia	2017	Sarhan et al., 2017
12	Brazil	2017	Avelar et al., 2019
13	Lebanon	2018	Daramsis et al., 2018
14	Norway	2018	Bygballe et al., 2018
15	India	2019	Ramani and KSD, 2019
16	Pakistan	2019	Shahbaz and Shaikh, 2019
17	The UK	2019	Meng, 2019
18	Canada	2020	Mohammadi et al., 2020
19	Morocco	2020	Bajjou and Chafi, 2020
20	Malaysia	2020	Ibrahim et al., 2020
21	Russia	2020	Minnullina and Solopova, 2020
22	Denmark	2021	Neve et al., 2021
23	Russia	2022	Orlov and Kankhva, 2022

Legend: Sorted chronologically

Figure 2. Contexts of studies addressing barriers, enablers, and implications of implementing LC.

3.4. Thematic and Content Analysis

The thematic analysis method was employed for analyzing the located studies [99]. This was accomplished through coding the obtained research data with an inductive approach. According to this study's objectives, the codes representing barriers, enablers, and benefits/implications of implementing lean construction were structured under three separate themes entitled "LC barriers", "LC enablers", and "LC implications". The mentioned themes included 17, 20, and 20 studies, respectively; therefore, 57 studies (in total) were analyzed under the established themes and were the sources of the obtained results. Then, the codes under the developed theme were further analyzed for three main purposes: first, to identify barriers, enablers, and implications of implementing lean construction; second, to develop syntheses of the detected barriers, enablers, and implications; and third, to model the findings based on their relatedness with each other.

Developing the synthesis of the discovered barriers, enablers, and implications was undertaken based on the similarity or sameness of the meaning and/or title. According to the number of detected barriers, enablers, and implications in each category, certain cut-off number for frequency of appearance on the ligature was chosen to qualify the most important ones. Regarding the barriers, those with three or more frequencies of appearance were selected as the key ones. Concerning the enablers, two or more frequencies of appearance were utilized as the selection criteria. All the identified implications, however, were qualified as important due to their low number compared to the enablers and barriers.

Then, the selected enablers, barriers, and implications were analyzed further to explore their relatedness. This analysis was performed in two steps. First, the barriers and enablers were analyzed based on their conceptual relevance to see which enabler contributes toward overcoming any of the barriers. Then, the same type of analysis, based on conceptual relevance, was conducted for matching the relevant enablers and implications. The obtained results from the explained analysis were combined, resulting in the development of a model.

4. Results

4.1. Barriers and Enablers of Implementing Lean Construction

The first and second groups of findings answer RQ1 and present the discovered barriers and enablers of implementing lean construction. Moreover, the representing contexts of those barriers and enablers are presented in Table 1. The term "representing contexts" in Table 1 refers to those countries in which the studies addressing barriers and enablers have been conducted. The term "frequency of appearance" in Table 1 refers to frequency of appearance of the identified barriers and enablers in the literature. As can be seen in Table 1, a lack of awareness and understanding of LC, resistance to change, and a lack of support and commitment from top management are the top three enablers (see Appendix A for references). It is also important to note that it is difficult to make any interpretation or comparison concerning the identified enablers and barriers solely based on the presented contexts in Table 1. This difficulty is mainly due to the limited and uneven number of the conducted studies and their representing contexts which have addressed the barriers and enablers of implementing lean construction. This statement also applies to the identified implications of LC implementation, which are presented in the following sub-section.

Regarding the enablers, as can be seen in Table 1, developing lean culture through promoting lean education, training and research, the application of lean principles tools and techniques, and top management support and commitment to lean construction, are the top three enablers for adopting and implementing lean construction (see Appendix B for references).

4.2. Implications of LC Application

The third group of results answers RQ2 and shows the positive consequences of adopting and implementing lean construction principles, practices, and techniques as well as tools (See Table 2). Moreover, Table 2 also presents the representing contexts of those identified implications. The term "representing contexts" in Table 2 refers to those countries in which the studies addressing implications of LC implementation have been conducted. As can be seen in Table 2, time and cost reduction, increased productivity (at task and project levels), and increased labor productivity are the top three implications of adopting and implementing lean construction (see Appendix C for references).

4.3. Relatedness between Barriers, Enablers, and Implications of Implementing Lean Construction

Discovering the barriers, enablers, and implications of implementing lean construction provided a basis for exploring their relatedness. Figure 3 shows the relatedness between the identified barriers (Table 1) and enablers (Table 1) and between the enablers and implications (Table 2). The first thing to note in Figure 3 is the considerable relatedness between the identified barriers and enablers and between the enablers and detected implications. This match can be also seen as an indication of the reliability of the findings.

Table 1. Barriers and enablers of implementing lean construction.

Barrier	Frequency of Appearance	Representing Contexts
Lack of awareness and understanding of LC	12	Bangladesh, China, Hong Kong, India, Jordan, Morocco, Palestine, Sweden,
Resistance to change (management and employees)	8	Australia, Bangladesh, China, India, Germany, Sweden
Lack of support and commitment from top management	6	China, Jordan, Germany, India
Lack of required competencies both at managerial and employee level	6	Bangladesh, China, Morocco
Lack of lean consultants, education, and training	5	Bangladesh, China, Jordan, India
Insufficient funds	5	Bangladesh, China, India, Morocco
Lack of effective communication among project participants	5	Bangladesh, Germany, India, Hong Kong
Insufficient support from the government (providing required policies, codes, and regulations)	4	India, Palestine, Peru
Lack of performance measurement systems	3	India, China
Poor understanding of customer needs and poor customer focus	3	India
Lack of involvement and transparency among stakeholders	3	Jordan, China
Enabler	**Frequency of Appearance**	**Representing Contexts**
Developing lean culture through promoting lean education, training, and research	9	Brazil, Türkiye, the USA, Chile, China, Saudi Arabia, India
The application of lean principles tools and techniques	5	Türkiye, the USA, Saudi Arabia
Top management support and commitment	4	Norway, Iran, Saudi Arabia, India
Continuous improvement in process and product development	3	Chile, South Africa, Saudi Arabia,
Creation and management of relevant knowledge	2	Brazil, Malaysia
Developing LC-oriented KPI for contractors	2	Malaysia
Improving organizational resilience by establishing LC-oriented leadership and culture, enhancing change readiness, and explaining networks and relationships	2	Saudi Arabia
Adopting collaborative project delivery models (e.g., alliance, lean project delivery, partnering)	2	Saudi Arabia, China
Promoting a culture of teamwork	2	Saudi Arabia, Malaysia
Investor/client requirement	2	The UK

Table 2. Implications of adopting and implementing lean construction.

Implications of LC Application	Frequency of Appearance	Representing Contexts
Time and cost reduction	8	India, Canada, Russia, the USA, Morocco, Türkiye, Brazil
Increased productivity (at task and project levels)	4	India, the UK, Saudi Arabia, Brazil
Increased labor productivity	3	Iran, Russia, Denmark
Increased process efficiency	3	Iran, Morocco, Saudi Arabia
Competence-based selection in bidding phase	2	Canada, France
Decreased inventory	2	Taiwan, Saudi Arabia
Better operational performance	2	Malaysia, Pakistan
Quality improvement	2	Brazil, Saudi Arabia
Waste reduction	1	The USA
Better diffusion of LC in managerial levels of company	1	The UK
Establishment of collaborative climate	1	Sweden
Stakeholder satisfaction	1	Saudi Arabia
Better health and safety	1	Saudi Arabia
Increased market share	1	Saudi Arabia

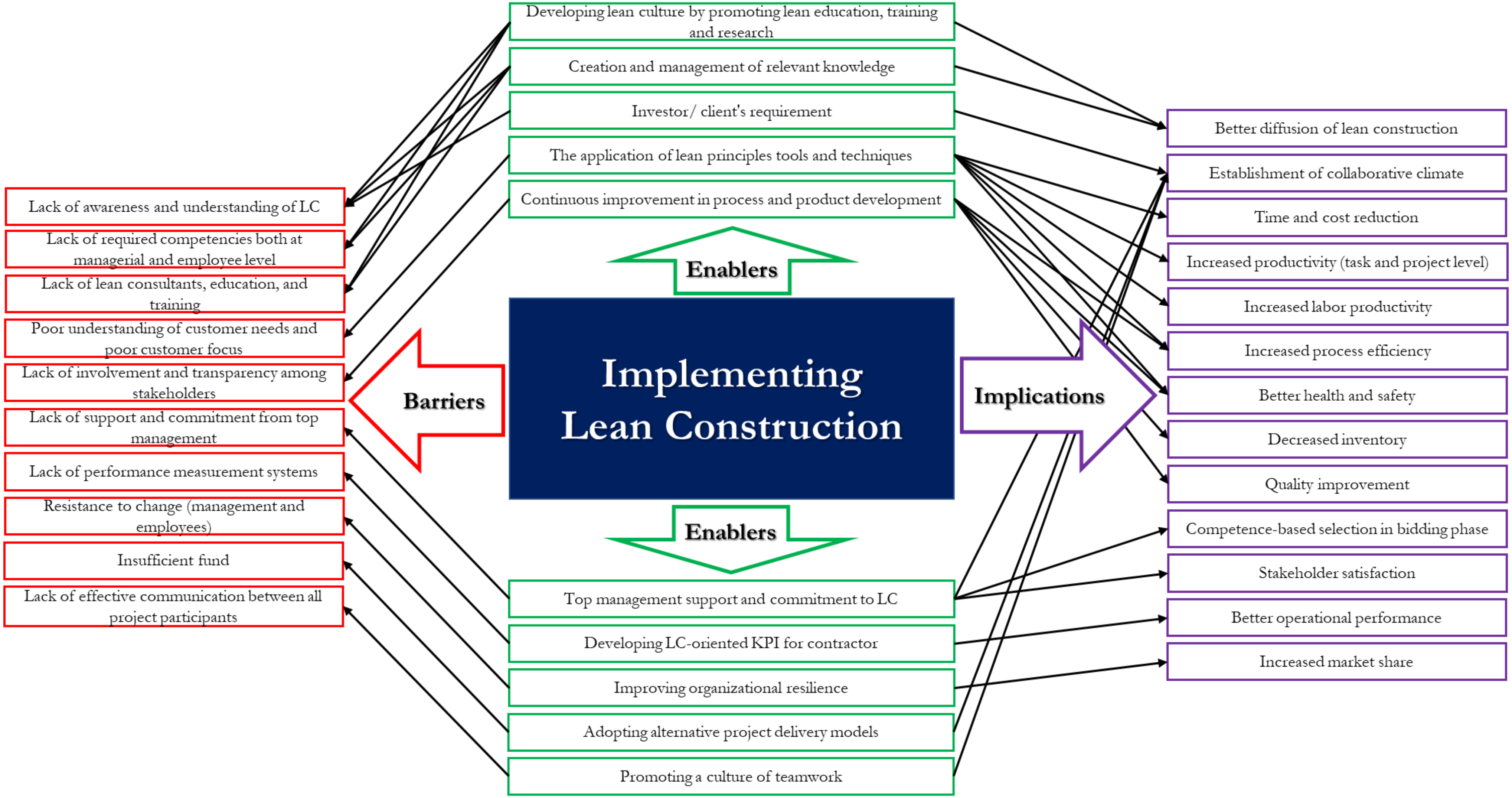

Figure 3. Relatedness between LC-implementation barriers, enablers, and implications.

As can be seen in Figure 3, the lack of awareness, competence, and consultants concerning lean construction can be overcome through developing lean culture by promoting education, training, and research and appropriate knowledge management. These actions seem to result in establishment of collaborative climate in projects and better diffusion of lean construction. In addition, poor understanding of customer needs and poor customer focus can be fixed through applying lean construction principles, tools, and techniques, thereby leading to time and cost reduction, increased productivity, increased process efficiency, and better health as well as safety.

Moreover, a lack of involvement and transparency among stakeholders can be resolved through continuous improvements in the process and product development, which seem to result in increased process efficiency, better health and safety, decreased inventory, and quality improvement. The complete details of the relatedness between LC implementation barriers, enablers, and implications can be seen in Figure 3.

5. Discussion

The first and second groups of findings presented barriers and enablers of the adoption and implementation of lean construction. Looking at Table 1, the first impression from the findings is that there is an interesting match between the discovered barriers and enablers, which can be seen as an indication of this study's reliability. In addition, the root cause of identified enablers and barriers seems to be related to "people" on three levels. The first level is individual and involves two main elements which are character (motives and traits) and leadership competence. The second level is corporate, which includes the four elements of working culture, process, change readiness, and capability in terms of finance and knowledge. Finally, the third level is the governance and refers to the role of regulatory bodies. This level has three elements which are policies, codes, and regulations. Figure 4 shows the explained levels.

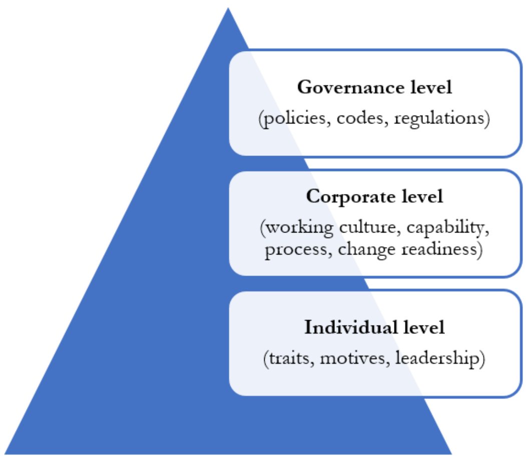

Figure 4. Level of the influence of "people" over success or failure of adopting and implementing lean construction.

The third group of findings revealed the implications of applying lean construction. If we look at these implications from a life cycle perspective, it is interesting to see not only do they cover all life cycle phases of construction projects, but they also involve pre-project (better diffusion of LC) and post-project (increased market share) stages. Among the listed implications in Table 2, competence-based selection in the bidding and establishment of a collaborative climate has the most relevance to the project definition phase. Increased process efficiency, time and cost reduction, labor productivity, and quality improvement are those which are related to both the design and planning and construction phases. Finally, decreased inventory, better operational performance, waste reduction, and better health and safety seem to be mostly related to the construction phase only. The significance of people's role in the success of adopting and applying LC and the inclusiveness of LC implications in terms of the project life cycle seem to imply an interesting message: developing people and investing on them with long-term vision seem to pay off throughout project life cycle with great benefits which again can only be attributed to people (e.g., higher efficiency of the human resources).

Finally, the last group of findings demonstrated the relatedness between the identified barriers, enablers, and implications. The first interpretation from Figure 3 is that the identified LC enablers and implications clearly reflect the five common challenges which the construction industry has faced. These challenges are safety (accident-free construction), quality (doing it right in the first time), reliability (reliable planning and higher percentage of completion), decision-making (fragmented design and construction), and value for money (competence-based tender instead of price-based) [100,101]. The content of Figure 3 can also be discussed from the lens of the project delivery system and its elements, which are the operational system (the timing and sequence of management events, practices, and techniques), project organization (the roles and relationships of the participants), and contractual relationships (the project parties' commitments) [102]. Through this lens, the listed barriers, enablers, and implications in Figure 3 can categorized into three groups based on their relevance to the mentioned project delivery elements. Accordingly, it can be said that LC education, training, and research which contribute toward the establishment of LC culture and result in a better diffusion and adoption of LC seems to be related to project organization. In addition, the application of lean principles and techniques and the continuous improvement of the process and product and collaborative delivery system which result in project efficiency and effectiveness in terms of time, cost, quality, and safety lead to the realization of a successful operational system. Finally, the most relevant implications to the contractual relationships (as the third element of project delivery) seem to be increased market share, stakeholder satisfaction, competence-based selection in the bidding phase, and the establishment of a collaborative climate between project parties.

This study's findings have obvious implications for theory and practice. In terms of the theoretical implications, it can be said that revealing the multilevel influence of people on the adoption and implementation of lean construction enriches the current theory and practice by emphasizing the critical role of human resources and the need for more investment and development in this area. Moreover, the comprehensive assessment of the barriers, enablers, and implications of LC adoption and application provides a frame of reference for future studies. Regarding practical implications, the findings can be insightful for project and company leaders who are interested in adopting and applying lean construction. Moreover, the obtained results can be also very useful for those projects and/or companies which have started LC implementation but are struggling with the barriers and their solutions (enablers) which have been identified in this study.

6. Conclusions

This study aimed to address the enablers, barriers, and implications of implementing lean construction in a comprehensive manner through discovering them separately and exploring their possible relatedness. This was accomplished through undertaking a systematic literature review and thematic, as well as content, analysis of the extracted research data. The obtained results provide the basis for the following conclusions:

- People are the main root cause of the barriers, enablers, and implications of LC adoption and implementation, and investing in, as well as developing, people pay off throughout the project life cycle.
- People directly influence the successful implementation of lean construction on three levels: (i) individual level (traits, motives, and leadership), (ii) corporate level (working culture, capability, process, and change readiness), and (iii) governance level (policies, codes, and regulations).

- A lack of awareness and understanding of LC, resistance to change (management and employees), and a lack of support and commitment from top management are the top three barriers for adopting and implementing lean construction.
- Developing lean culture through promoting lean education, training and research, the application of lean principles tools and techniques, and top management support and commitment to lean construction are the top three enablers for adopting and implementing lean construction.
- Time and cost reduction, increased productivity (at task and project levels) and increased labor productivity seem to be the top three implications of applying lean construction.

The obtained results contribute to a body of knowledge on lean construction and provide practical knowledge for project professionals in their efforts to adopt and implement lean construction. As a limitation of this study, it is acknowledged that certain keywords were utilized in the Scopus database for locating the relevant studies, which might have affected the reliability and external validity (generalizability) of the study. The findings raised some questions which can be recommendations for the future studies:

- To what extent do contextual differences (e.g., working culture, regulations) affect the adoption and implementation of lean construction?
- What kind of support from regulatory bodies in developing and developed counties can contribute toward the wider application of lean construction?

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. LC implementation Barriers

Barrier	[26]	[23]	[64]	[59]	[67]	[24]	[62]	[69]	[61]	[63]	[68]	[22]	[60]	[25]	[65]	[66]	[58]	Frequency of Appearance	Rank
Lack of awareness and understanding of LC	*	*				*	*	*	*		*	*	*	*		*	*	12	1
Resistance to change (management and employees)	*	*			*			*	*	*				*	*			8	2
Lack of support and commitment from top management		*			*		*	*		*	*								
Lack of required competencies both at managerial and employee levels		*			*			*	*			*	*					6	3
Financial constraints	*							*	*		*	*	*						
Lack of lean consultants, education, and training	*	*					*	*	*							*		5	4
Lack of effective communication between all project participants									*	*	*	*					*		
Insufficient support from the government (providing required policies, codes, and regulations)	*	*	*			*												4	5
Lack of performance measurement systems	*				*			*											
Poor understanding of customer needs and poor customer focus	*	*			*													3	6
Lack of involvement and transparency among stakeholders		*					*	*											
Lack of planning for quality	*	*																	
Project subcontracting	*							*											
Implementation costs and time		*	*																
Lack of incentives and motivation		*						*											
Centralized decision-making		*			*														
Complexity of lean in eyes of workers		*						*											
High turnover of workforce		*						*											
Limited use of off-site construction techniques and prefabrication		*						*											
Fragmented and cyclic nature of the construction projects		*							*									2	7
Lack of commitment (managerial)					*				*										
Lack of appropriate lean technology or tools								*	*										
Insufficient standardization								*				*							
Absence of organizational culture representing LC								*	*										
Traditional design approach									*			*							
The dominance of the traditional management practice									*			*							
Lack of information and knowledge sharing and integrated change control										*				*					
Inefficiency in resource planning										*				*					
Traditional culture and attitude of employees												*			*				
Lack of long-term relationships with suppliers		*																	
Lack of technical capabilities and green initiatives	*																	1	8
Not recognizing financial advantage	*																		
Cultural differences	*																		

Barrier	[26]	[23]	[64]	[59]	[67]	[24]	[62]	[69]	[61]	[63]	[68]	[22]	[60]	[25]	[65]	[66]	[58]	**Frequency of Appearance**	**Rank**
Slow and partially visible results of implementation		*																	
Inaccurate and incomplete drawings		*																	
Reluctance of project participants to share risk–reward		*																	
Lack of long-term philosophy		*																	
Inadequate administration of the necessary information to generate a learning cycle		*																	
Hierarchies in organizational structure		*																	
Lack of waste identification and control		*																	
Inadequate material delivery performance		*																	
Lack of integrated procurements		*																	
Stringent requirements and approvals during contracting		*																	
Lack of alliances between academy and organizations			*																
Size of construction project (it is difficult to implement LC in small-size construction projects due to the required capacity and capability)				*															
Lack of sustainable practices				*															
Lack of knowledge on how to apply LC techniques for safety improvement						*													
Severity of weather								*											
Poor materials								*											
Fierce market competition environment								*											
Tolerance of untidy workplaces								*											
Nonrecognition of LC advantages								*											
Low informatization								*											
Insufficient program planning								*											
Lack of effective supervision and control								*											
Excessive cost savings during construction								*											
Less personal empowerment								*											
Avoid making decisions and taking responsibility								*											
Insufficient attention to green and environmental protection								*											
Cooperation problems outside the construction department								*											
Misperception about lean practices										*									
Failure in operational excellence										*									
Lack of organizational communication										*									
Problem in teamwork and diverging aims in lean										*									
Nonuse of modern techniques and technologies												*							
Lack of trust														*					
Choice of contracting mode																*			
Lack of integration of design and construction																	*		

Appendix B. LC Implementation Enablers

Enabler	[83]	[78]	[77]	[82]	[9]	[80]	[51]	[72]	[73]	[84]	[52]	[54]	[81]	[74]	[76]	[70]	[71]	[53]	[79]	[75]	Frequency of Appearance	Rank
Developing lean culture through promoting lean education, training, and research	*		*		*		*	*				*	*						*	*	9	1
The application of lean principles tools and techniques		*	*										*	*				*			5	2
Top management support and commitment to lean construction				*							*		*						*		4	3
Continuous improvement in process and product development						*	*						*								3	4
Creation and management of relevant knowledge	*															*					2	5
Developing LC-oriented KPI for contractor		*														*						
Improving organizational resilience by establishing LC-oriented leadership and culture, enhancing change readiness, and expanding networks and relationships		*											*									
Adopting alternative procurement methods in project delivery (e.g., design, build)													*							*		
Promoting a culture of teamwork during construction projects													*			*						
Investor/client requirement															*		*					
Stabilizing environment through adoption of last planner system	*																				1	6
Increasing process transparency through visualization tools such as BIM and Kanban	*																					
Building trust	*																					
Understanding current waste reduction practices at the targeted construction site						*																
Educating all contractors on the project about lean construction and its benefits						*																
Specifying value						*																
Identify value stream						*																
Establish flow of products						*																
Pull production						*																
A proactive interaction with contractor upper management and project organizations							*															
Collaboration among companies							*															
Bottom-up strategy								*														
Adopting 4P Toyota Way model (philosophy, process, people and partners, and problem solving)									*													
Effective changes in decision-making mechanism										*												
Sufficient time												*										
Adopting new construction technologies and methods (e.g., BIM)													*									
Clear definition of client requirements													*									
Applying lean methodology at an early stage of the building project delivery (e.g., planning, design stage)													*									
Coordinating and promoting efforts at a national level (e.g., establishment of National Lean Construction Institute)													*									
Establishing long-term relationships within the supply chain													*									
Collaborative practices														*								

Enabler	[83]	[78]	[77]	[82]	[9]	[80]	[51]	[72]	[73]	[84]	[52]	[54]	[81]	[74]	[76]	[70]	[71]	[53]	[79]	[75]	Frequency of Appearance	Rank
Deploying lean construction systematically																				*		
Root cause analysis to investigate problems														*								
Willingness to invest in lean practices			*																			
Morning huddles for lean			*																			
Effective communication of LC-implementation/application info to the whole company				*																		
Showing success from early adopters				*																		
Ensuring involvement of company's HR in implementation process				*																		
Establishing a forum for exchanges of experiences				*																		
Competent human resources											*											
Effective communication between parties											*											
Support of government and regulatory bodies											*											
Planning it right																*						
Understanding the whole construction life cycle in a non-price factor view																*						
Benchmarking																*						

Appendix C. Implications of LC Implementation

Implication	[21]	[29]	[19]	[85]	[20]	[89]	[87]	[95]	[88]	[97]	[55]	[28]	[93]	[94]	[27]	[92]	[56]	[30]	[57]	[90]	Frequency of Appearance	Rank
Time and cost reduction	*				*			*	*				*		*	*			*		8	1
Increased productivity (task and project levels)	*									*								*	*	*	4	2
Increased labor productivity											*		*	*							3	3
Increased process efficiency											*				*			*				
Competence-based selection in bidding phase			*		*																2	4
Decreased inventory				*														*				
Better operational performance												*					*					
Quality improvement																		*	*			
Waste reduction		*																			1	5
Better diffusion of LC at managerial levels of company						*																
Establishment of collaborative climate							*															
Stakeholder satisfaction																		*				
Better health and safety																		*				
Increased market share																		*				

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