Ain Shams Engineering Journal 15 (2024) 102324

Contents lists available at ScienceDirect

Ain Shams Engineering Journal

journal homepage: www.sciencedirect.com

Influence of the experience of the project manager and the foreman on project management's success in the context of LPS implementation

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ARTICLE INFO

Article history:
Received 9 February 2023
Revised 2 May 2023
Accepted 22 May 2023
Available online 01 June 2023

Keywords:
Last Planner System (LPS)
Building projects
Qualitative comparative analysis (QCA)
Mann–Whitney *U* test
Project success

ABSTRACT

Production planning is a key element for success in building project management. Last Planner System (LPS) has emerged as an alternative proactive management method through the commitment of the different stakeholders involved in the project; however, further research is required to determine the factors that can affect the success of LPS implementation. This research aims to analyze how the implementation of LPS and the construction management experience of the project manager and the construction site foreman individually influence project management's success, getting minimum time and cost deviations. In this work, newly built single-family house projects were analyzed. Quantitative and qualitative analyses, based on the Mann–Whitney *U* test and qualitative comparative analysis method, respectively, were performed to constrain both the individual and combined effects of LPS, the project foreman, and the project manager in terms of cost and time deviation as measures of project management success. The results highlight that LPS implementation is significant in terms of time deviation and combined LPS implementation and the foreman's experience in construction management are sufficient to maintain time deviations below 10%. However, among the studied variables, only the foreman's experience is a required condition to maintain cost deviations under 10%. Overall, this study may help construction organizations to improve their managerial practices at construction sites.

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1. Introduction

Lean construction is emerging as a new management and production approach in the construction industry [1-4]. In the field of lean construction, the Last Planner System (LPS hereafter) is a proactive and collaborative method, primarily used for planning and controlling construction projects on-site [5-8]. LPS increases reliability through a three-level planning approach [9-11]: comprising a master plan with a pull session, a look-ahead planning that filters the make-ready activities, and a weekly planning that ensures that planned work is completed. LPS implementation requires the commitment of the project manager, construction site foreman, subcontractors and squad leaders [6,9,12]; this commitment is a key factor of leadership in senior and mid-level managers [13-19]. In addition, Koskela [4] emphasized the role of the site manager in the success of LPS implementation.

At the construction project level, the project manager represents the leader of the construction team [20-22] and is in charge of project planning, scheduling, and communications [23,24]. Within the construction site, the foreman is responsible for the construction activities and overseeing the daily production and acts as the link between management and the construction workers [15,25]. The foreman's responsibilities include coordinating trades working in the same area, assigning work to each worker when they have finished their last assigned job, controlling the movement of materials to the point of installation, etc. [4,10,26]. Notably, some authors [16] use the term "field supervisor" instead of foreman; however, the latter term is used throughout the present study. The construction site foreman can ensure predictable workflow downstream by coordinating daily tasks, creating schedules for workers, controlling work pace and quality, reading blueprints, and budget management [12,13].

Project managers and foremen require a range of competencies to effectively perform their jobs; however, these competencies are not necessarily the same for each role [16]. The project manager competencies have been analyzed in detail in the literature and comprise three main competences or skills [23,27-29]: technical,

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https://doi.org/10.1016/j.asej.2023.102324
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organizational, and human. The foreman, as a lower-level manager, also requires some of these competencies, with more emphasis on the human skill category [15,25,30].

Sometimes, project managers and foremen are seen as negotiators and facilitators that seek to achieve collaboration among the parties involved in the project [16,31]. Some authors [18,19,32,33] have analyzed how collaboration among different construction site stakeholders, as well as the concepts of power and dependence, can be influenced by factors such as commitment, reliability, and trust; both lean construction in general, and LPS more specifically are also built on these three factors [4,10,34]. Some studies have also focused on the importance of the level of commitment of team members [35-37]. Sauer et al. [20] highlight the importance of commitment, but linked this factor to experience, whereas Ceric [38] suggests that trust increases with the project manager's experience.

Experience has been discussed extensively in the construction project literature. Many authors have highlighted the importance of experience in mid- and low-level management at construction sites [11,16,39,40]. Leadership and human skills typically increase with the personal experience of project managers and foremen [41-43]. In addition, organizations will tend to select their most experienced project managers and foremen to lead complex projects [44]. Rojas (p. 429, 2013) [16] states that: "no amount of technical knowledge can offset a lack of experience"; in this context, experience not only deals with the technical competencies but also with non-technical ones [45]. Viana et al. [46], who analyzed the implementation of LPS through two case studies, suggested that project managers and foremen with a lack of experience in construction site activities will tend to be affected by insufficient look-ahead planning or ineffective short-term planning meetings.

Many authors have observed that LPS has been successfully implemented across many building projects [35-37,47-50], where its implementation has led to improvements in short-term compliance, work productivity, workflow variability, schedule performance, and reduced cost deviations [51,52]. However, other authors have highlighted a current lack of empirical data and, therefore, a lack of knowledge, concerning the critical factors driving of effective LPS implementations [34,53,54]. One of the key potential drivers is the influence of the experience of the project manager and foreman in successful management when LPS is implemented [6,11,15]. Thus, this study aims to analyze how the construction management experiences of the project manager and site foreman influence project cost and schedule performance depending on whether LPS is implemented or not. In this work, successful project management is measured in terms of project costs and schedule performance.

This paper is structured as follows. Section 2 describes the current research gap and the goals of this study. The next section describes the study's research methods, based on quantitative and qualitative analysis, which are used to assess the role of LPS and management experience in the performance of new-build Spanish single-family house construction projects. Section 4 presents and discusses the study's results in the context of the current body of knowledge in this field. Finally, in section 5, the work's conclusions are drawn, its contributions are highlighted, and a range of implications for theory and practice, limitations, and future research suggestions are presented.

2. Knowledge gap and research goal

The levels of technical, organizational, and human competencies of the project manager and site foreman have a significant influence on construction project performance [6]. Many authors have described the influence of the project manager and site foreman's experience on the project management's success [15,16,38,41,42]. Additionally, several studies have highlighted the benefits of collaboration, with LPS as a key example approach, in terms of construction project planning and control [11,19,55]. However, the role that these factors play in the success of LPS implementation has been only briefly analyzed in the literature; moreover, no studies to date have specifically analyzed the influence of managers' experience levels in successful construction project management when implementing LPS.

Given these limitations, this study aims to contribute to the body of knowledge in this field by analyzing how the project manager's experience, the foreman's experience, and the implementation of LPS individually influence successful construction project management, getting minimum time and cost deviations. In terms of the scope of this work, the present study focuses on the Spanish building residential subsector. Residential building projects represent a fundamental part of society and, in many countries, form one of the most significant parts of the construction industry's market [1]. In Spain, the construction of residential housing is one of the most important components of the market [56], representing 34% of the country's total of new buildings [57].

3. Research methods

3.1. Overall approach

As described above, the goal of this research is to gain improved insights into how the project manager's experience, the foreman's experience, and the implementation of LPS individually influence the successful management of a construction project, getting minimum time and cost deviations. Cost, time, and quality have represented the triple constraints of the project management triangle for many years; however, the time and cost measurements are increasingly important due to their capability to establish a crucial benchmark for assessing project performance and project efficiency [58]. Thus, in this work, the project management's success is measured through schedule performance and cost performance [59].

This research combines quantitative and qualitative approaches to obtain a comprehensive overview of the role of LPS and the construction management experience of both the project manager and construction site foreman in project performance, using new-build Spanish single-family houses projects as case studies. In the first phase, researchers implemented a structured interviews to collect the data; the responses were obtained face to face in order to clarify any doubts on the questionnaire [56]. The questions were designed to characterize the project and gather information about cost and time performance.

After the data collection, the analysis focused on assessing the influence of the LPS implementation and construction management experience of the project manager and the construction site foreman on project outcomes. First, the quantitative time and cost deviation were assessed statically using the Mann–Whitney *U* test. Second, a qualitative analysis was performed to assess the influence of the combinations of these three variables in terms of time and cost performance. For this second analysis, the cost and time deviation were transformed into categorical variables depending on whether the cost and time variance values were over 10%. The Qualitative Comparative Analysis (QCA) method was selected to evaluate the combined effects of the three variables on schedule success and cost performance. The QCA technique has been primarily used in political science and sociology [60]; however, in recent decades, this qualitative technique has also become increasingly important in the construction industry too [61-65]. QCA provides good results when analyzing the interactions between conditions and outcomes [60], generalizing for small samples of cases, and determining causal models [66].

3.2. Data collection

In this study, a questionnaire was used for data collection. The aim of this questionnaire was for participants to share project practices relating to projects completed from 2015 to 2020. To ensure proper control of the collected data and facilitate the analyses, the questionnaire was defined using multiple-choice and open-ended questions and was divided into two parts. Part one concerned the project characteristics, including procurement procedure (lowest price or best value), building size (m^2), total cost estimation (€), real total cost (€), and construction duration estimation (months), real construction duration (months). The second part collected information about the project's management characteristics, including project manager's construction management experience with similar facilities (years), the foreman's construction management experience with similar facilities (years), whether LPS was implemented in the project (yes or no), and whether the construction team had previous experience in LPS implementation in at least one similar project (yes or no).

Following Pellicer et al. [56] and Molenaar et al. [67], the questionnaire validation process comprised two steps. The first step aimed to assess the completeness and clarity of the document. This assessment was performed by 10 experts with over 15 years of experience in the Spanish building residential subsector. The second step involved performing pilot interviews to ensure a correct understanding of the survey's questions. Three pilot interviews were performed with contractors to guarantee a complete understanding of the questionnaire and to ensure reliable data collection for future analysis. The validation resulted in minor changes to the questionnaire. Once the questionnaire was validated, contractors were selected from professional associations by convenience sampling. A total of 30 contractors were interviewed; however, only 20 case studies were chosen for the analysis. Of the total, 10 case studies were not used due to incomplete information. The selection of cases was based on an analysis of projects with similar features.

3.3. Data analysis

3.3.1. Quantitative analysis

In the quantitative analysis step, the data were first analyzed using non-parametric statistics. Specifically, the Mann–Whitney *U* test was applied; this test is used when the samples are not normally distributed and facilitates comparison of two independent samples [68,69]. The Mann–Whitney *U* test compares the two sample's medians and determines whether there is a statistically significant difference between the samples in the data set. This statistical analysis is widely used because it is extremely robust. A p-value lower than 0.05 indicates a statistically significant difference between the groups' means [69]. Thus, the Mann–Whitney *U* test allows an analysis of the presence of statistically significant differences between the categories of each of the independent variables (see Table 1): (1) LPS implementation; (2) the level of construction management experience of the project manager; and (3) the level of construction management experience of the foreman. These variables are assessed in terms of two dependent variables: cost deviation [1+ (Real Cost – Budgeted Cost) / Budgeted Cost)] and time deviation [1+ (Real Duration – Expected Duration) / Expected Duration)]. None of the project managers or foremen involved in the 20 analyzed projects had extensive prior experience with LPS implementation; therefore, the experience of these agents with LPS implementation was not analyzed.

Table 1
Independent variables.

Independent variables	Definition
LPS implementation	0: No; 1: Yes
Experience of the project manager with similar facilities	0:<15 years; 1:>=15 years
Experience of the foreman with similar facilities	0:<15 years; 1:>=15 years

3.3.2. Qualitative comparative analysis (QCA)

QCA is an appropriate technique for use with a small sample of cases, which allows causal models to be identified [66]. QCA provides good results in analyzing the interactions between conditions and outcomes [60]. The conditions refer to the independent variables, while outcomes refer to the dependent variables. In this work, two QCAs have been performed: one QCA was performed with cost deviation as the dependent variable (or outcome variable), and a second QCA was performed with time deviation as the dependent variable. In both QCAs, the independent variables (or conditions) were: LPS implementation, experience of the project manager with similar facilities, and experience of the foreman with similar facilities. This method requires categorizing all the study's variables; therefore, the dependent variables (cost and time deviation) were transformed into categorical variables (0: deviation < 10%; 1: deviation >= 10%), and the independent variables were categorized as shown in Table 1.

Once the variables are categorized, QCA identifies necessary and sufficient conditions for the desired outcome. Necessary conditions refer to those independent variables that almost always correspond to project success, whereas sufficient conditions are those combinations of independent variables that typically correspond to the project's success [59]. We define the project's success as when the dependent variable is equal to "0″ (i.e., deviation < 10%). The description of necessary and sufficient conditions can help practitioners understand which factors should be considered more significant to guarantee the project's success.

To identify the necessary and sufficient conditions, the QCA technique involves the following steps: (1) truth table definition; (2) identifying the necessary conditions; and, (3) identifying sufficient conditions. In this work, researchers implemented this analysis in fsQCA version 3.0 software [70].

The truth table illustrates the relationship between independent variables and dependent variables, analyzing each case independently [71]. This table shows the configuration of the independent variables based on the sample of cases and their observed outcomes. If there are 'n' independent variables, the truth table contains a number of rows equivalent to the number of possible logical combinations of the independent variables (2^n) [72]. In this study, as there are three independent variables and each independent variable has two categories, there were eight (2^3) rows in the truth table. After defining the table, the rows that do not represent any cases of the sample are deleted. The raw consistency examines the goodness of each possible configuration of the independent variables as the proportion of cases with a positive outcome (i.e., where the dependent variable is equal to 0 in this instance)[65].

The necessary conditions are the conditions (category "1″ of an independent variable) that must be present to achieve a certain outcome [65]. The goodness of the necessary condition is measured through each condition's consistency and coverage scores for each individual condition [70]. Consistency describes "the degree to which a causal condition is a superset of the outcome" (Ragin, p.20) [70]. Therefore, the consistency is calculated for each independent variable as the proportion of cases that having the category "1" cases of the independent variable that correspond to a positive outcome. The consistency score is measured between 0 and 1, where a value of 0 indicates no consistency and a value of 1 indicates complete consistency. The coverage metric measures "how much of the outcome is covered (or explained) by each solution term and by the solution as a whole" (Ragin, p. 60) [70]. Coverage is calculated for each independent variable as the relation of the number of cases that having the category "1" of the independent variable present a positive outcome with respect to the total of cases with a category "1" of the independent variable. Coverage is also measured between 0 and 1, where a value of 0 indicates no coverage and 1 indicates full coverage. A necessary condition is defined as one with a consistency score greater than 0.8 and a coverage score greater than 0.25 [73].

Finally, the sufficient conditions were determined as the combinations of the independent variables that influence positive outcomes. QCA has three different solution types: complex, parsimonious, and intermediate. In the complex solution, no positive cases are set to "false". In the parsimonious solution, the positive cases are selected as true, the negative cases are selected as false, and the remainders are excluded., The intermediate solutions use only the logical remainders that "make sense" given the researchers' substantive and theoretical knowledge [60]. The authors selected the complex solution approach because this method relies only on observed conditions and does not make assumptions about any unobserved conditions or configurations [70]. The complex solution shows the configurations that are sufficient to achieve cost or time deviations below 10%. These solutions are assessed in terms of their consistency, raw coverage, unique coverage, and solution coverage. The raw coverage is calculated as the proportion of outcome cases that are covered by a configuration [70]; the unique coverage is the proportion of outcome cases that are uniquely covered by a configuration (i.e., there are no other configurations that cover those cases), and solution coverage is the proportion of cases that are covered by all the configurations [70].

4. Results and discussion

4.1. Descriptive statistics

This study investigated 20 Spanish new-build single-family houses projects. The 20 case studies were selected based on projects with similar features: Spanish single-family house projects involving new buildings, private owners, low-bid procurement procedures, total costs estimated between 300,000€ and 800,000€, and estimated construction times between 12 and 15 months. Table 2 summarizes the sample distribution in terms of building size, real and estimated total cost and total construction duration, and unit costs based on building size and total construction duration. The cost data were updated to January 2020 to reflect economic inflation. Note that the analysis period includes only the construction stage.

LPS was implemented in six projects (see Table 3). A total of 40% of the project managers had over 15 years of construction management experience with similar facilities; however, 70% of the foremen had over 15 years of similar construction management experience.

4.2. Quantitative analysis

The statistical analysis assessed whether there were significant differences between the categories of each independent variable in terms of cost and time deviation. The data were analyzed using IBM SPSS Statistics software version 23.0. The Mann–Whitney *U* test results showed that, in terms of cost deviation, only the experience of the foreman corresponds to statistically significant differences in means ($p\text{-value} < 0.05$): projects with less experienced construction site foremen tended to have higher cost deviations (see Table 4). In terms of time deviation, the Mann–Whitney *U* test demonstrated that only LPS implementation significantly influences the results (see Table 5).

4.3. Qualitative comparative analysis results

Two QCAs were performed to identify the necessary and sufficient conditions to achieve cost and time deviation below 10%. Table 6 shows the coded data for each project. The outcomes (cost deviation and time deviation) were coded as 1 if the deviation was equal to or over 10% and 0 where the deviation was below 10%.

4.3.1. Truth table

To perform the QCA, the first step involved constructing the truth table. Table 7 shows the observed combinations of the three independent variables in the sample and the corresponding outcome variables. The truth table was defined for projects with cost deviations below 10% (denoted as $\sim$ cost deviation) and time deviations below 10% (denoted as $\sim$ time deviation). In this instance, the raw consistency measures the proportion of cases that show a positive outcome (i.e., deviation below 10%). For example, the first row of the truth table represents the cases where LPS was implemented in the construction process, and the construction management experience with similar facilities of both the project manager and the foreman was equal to or over 15 years. In this example, the raw consistency for the cost deviation was 1 because 100% of the cases that satisfied these conditions (P10, P14, and P16) were completed with cost deviations below 10%. Researchers eliminated the rows from the truth table if there is no observed case to indicate an outcome.

4.3.2. Necessary conditions

Necessary conditions represent those conditions that must occur to observe a certain outcome. The goodness of the necessary condition is measured through the consistency and coverage scores for each individual condition [70]. The consistency is calculated for each independent variable as the proportion of cases where category "1" of the independent variable corresponds to a positive outcome. For example, as shown in Table 8, the consistency of LPS implementation for cost deviation was 0.4 because although 10 projects achieved cost deviations below 10%, only four

Table 2
Sample overview.

Descriptive variables	Mean	Minimum	Maximum	Standard Deviation
Building size (m2)	382.5	248.0	572.0	92.4
Total cost estimation (thousands €)	414.9	285.0	655.0	138.1
Real total cost (thousands €)	466.9	325.0	785.0	144.3
Construction duration estimate (months)	12.1	10.0	15.0	1.1
Real construction duration (months)	15.4	12.0	23.0	2.7
Unit costs (thousands €/m2)	1.1	0.8	1.4	0.1
Unit costs (thousands €/month)	34.1	23.8	54.6	9.8

Table 3
Project characteristics.

Project	LPS implementation	Experience of the project manager with similar facilities	Experience of the foreman with similar facilities	Cost deviation (%)	Time deviation (%)
P1	No	>=15 years	>=15 years	3.94	33.33
P2	No	>=15 years	>=15 years	2.96	25.00
P3	No	<15 years	>=15 years	24.91	50.00
P4	No	<15 years	>=15 years	38.71	41.67
P5	No	<15 years	>=15 years	27.03	25.00
P6	No	>=15 years	>=15 years	14.49	16.67
P7	No	<15 years	>=15 years	10.84	25.00
P8	No	<15 years	>=15 years	5.89	41.67
P9	No	<15 years	<15 years	9.43	33.33
P10	LPS	>=15 years	>=15 years	4.58	0.00
P11	No	>=15 years	>=15 years	28.79	50.00
P12	No	<15 years	>=15 years	12.85	8.33
P13	LPS	<15 years	<15 years	19.87	20.00
P14	LPS	>=15 years	>=15 years	5.83	0.00
P15	No	<15 years	<15 years	21.71	25.00
P16	LPS	>=15 years	>=15 years	6.63	0.00
P17	LPS	<15 years	<15 years	21.61	80.00
P18	No	>=15 years	>=15 years	5.00	53.33
P19	No	<15 years	<15 years	5.17	33.33
P20	LPS	<15 years	>=15 years	6.01	0.00

Table 4
Variables influencing cost deviation significantly.

Statistics	Foreman's experience	
	<15 years	>=15 years
Min	1.052	1.030
Max	1.387	1.288
Mean	1.170	1.090
SD	0.104	0.087
Mann–Whitney U	0.037	

Table 5
Variables influencing time deviation significantly.

Statistics	LPS implementation	
	No	Yes
Min	1.083	1.000
Max	1.533	1.800
Mean	1.330	1.167
SD	0.132	0.320
Mann–Whitney U	0.030	

of them implemented LPS (4/10 = 0.4). The coverage was calculated for each independent variable as the relation of the number of cases that having the category "1" of the independent variable present a positive outcome with respect to the total of cases with a category "1" of the independent variable. As an example, as shown in Table 8, the coverage of LPS is 0.667 because four of the six cases that implemented LPS achieved cost deviations below 10% (4/6 = 0.667). To be identified as a necessary condition, the consistency score must be equal to or greater than 0.8 and the coverage score must be greater than 0.25 [59,73].

As shown in Table 8, in terms of cost deviations, the foreman's experience satisfies these conditions; thus, a project foreman with over 15 years of experience is a necessary condition to guarantee cost deviations below 10%. In terms of time deviations, LPS implementation and foreman's experience are necessary conditions (consistency $\geq$ 0.8 and coverage $\geq$ 0.25); however, a high coverage was only recorded for LPS implementation. According to Yu et al. [59], when a variable has low coverage (<0.4), it must be considered empirically insignificant, even if it has a high consistency value. In this instance, the foreman's experience variable has coverage equal to 0.333. Accordingly, only LPS implementation can be considered empirically significant to guarantee project time deviations below 10%.

These results are similar to those obtained with the Mann–Whitney *U* test and confirm that LPS implementation has a statistically significant effect on project management success in terms of reducing time deviation. Regarding cost deviation, the results highlight that the construction management experience of the foreman is the most significant variable. In contrast, LPS implementation does not exert a significant influence on cost deviations.

The positive influence of LPS implementation on the time performance of construction projects has been demonstrated by various authors [53,74]. Hicham et al. [37] and Fernandez-Solis et al. [6] highlighted that the positive effect of LPS in reducing time deviation is because the detailed scheduling in this method provides the stakeholder with consistent data about productivity, which is essential to reduce disruptions on-site, and improve in project communication and coordination [48]. Similarly, Koskela [4] stated that LPS implementation can reduce time deviation because the essence of LPS is scheduling properly, effectively, and efficiently, including milestone planning, phase scheduling, look-ahead planning, and weekly work plans [6]. In addition, Ballard [10] highlighted that LPS aims to optimize workflows by promoting the participation of all involved stakeholders in the project's production control system.

The foreman's experience variable describes the length of construction management experience with similar facilities. Project management experience refers to skills in terms of planning, leading, directing, and managing projects. In a construction management context, this experience type is associated with knowledge of project implementation, effective project management when organizational changes affect projects, and the involvement of different stakeholders based on the needs and interests of the project [75]. The results of the present study highlight the significance of the foreman's experience in minimizing cost deviations. Research performed in the 1980 s and 1990 s similarly emphasized the influence of the foreman's level of experience in terms of achieving the project's success [76-81]. Badger et al. (p. 423) [15] stated that "companies with the best foremen will be the long-term winners in the construction industry" and emphasized that contractors must work on improving both the technical and the management skills of their foremen as a differentiator of construction companies.

Table 6
Coded data for each project.

Project	LPS implementation	Experience of the project manager with similar facilities	Experience of the foreman with similar facilities	Cost deviation	Time deviation
P1	0	1	1	0	1
P2	0	1	1	0	1
P3	0	0	1	1	1
P4	0	0	1	1	1
P5	0	0	1	1	1
P6	0	1	1	1	1
P7	0	0	1	1	1
P8	0	0	1	0	1
P9	0	0	0	0	1
P10	1	1	1	0	0
P11	0	1	1	1	1
P12	0	0	1	1	0
P13	1	0	0	1	1
P14	1	1	1	0	0
P15	0	0	0	1	1
P16	1	1	1	0	0
P17	1	0	0	1	1
P18	0	1	1	0	1
P19	0	0	0	0	1
P20	1	0	1	0	0

Note: LPS implementation:0 = No; 1 = Yes. Experience of the project manager with similar facilities: 0:<15 years; 1:>=15 years. Experience of the foreman with similar facilities: 0:<15 years; 1:>=15 years.

Table 7
Coded data for each project.

LPS	Project manager's experience	Foreman's experience	~Cost deviation			~Time deviation		
			~CD	RC	Cases	~TD	RC	Cases
1	1	1	1	1	P10, P14, P16	1	1	P10,P14,P16
1	0	1	1	1	P20	1	1	P20
0	0	0	0	0.67	P9,P15, P19	0	0	P9,P15, P19
0	1	1	1	0.6	P1, P2, P6,P11,P18	0	0	P1,P2, P6, P11,P18
0	0	1	0	0.17	P3, P4, P5, P7, P8, P12	0	0.17	P3,P4,P5,P7,P8, P12
1	0	0	0	0	P13,P17	0	0	P13,P17

Note. CD: Cost deviation; TD: Time deviation; RC: Raw consistency.

Table 8
Analysis of necessary conditions.

Condition	~Cost deviation		~Time deviation	
	Consistency	Coverage	Consistency	Coverage
LPS implementation	0.4	0.667	**0.8**	**0.667**
Project manager's experience	0.6	0.750	0.6	0.375
Foreman's experience	**0.8**	**0.533**	**1.0**	0.333

4.3.3. Sufficient conditions

This study identified one combination of conditions that minimizes both the cost and time deviation among the case study projects (i.e., sufficient conditions): implementing LPS and having a foreman with more than 15 years of construction management experience. In terms of cost deviation, this sufficient condition showed full consistency (1) but medium coverage (0.4), indicating that this statement corresponds to only 40% of the cases that satisfy this combination (see Table 9). However, this sufficient condition corresponds to both high consistency (1) and coverage (0.8) for time deviations. Therefore, these results demonstrate that a sufficient condition to achieve time and cost deviations below 10%, is to implement LPS with a site foreman with more than 15 years of experience in construction management of similar facilities. This statement is empirically significant for time deviation since this combination of conditions represents 80% of the studied projects.

Another important result is that the project manager's experience in construction management does not significantly influence cost and time deviations; this factor is overshadowed by the influence of the foreman's experience and LPS implementation. In this context, Badger et al. [15] and Alarcón et al. [82] stated that effec-

Table 9
Complex outcome solutions. Configurations shown correspond to sufficient solutions.

Condition	~Cost deviation	~Time deviation
LPS implementation = 1	P	P
Project manager's experience = 1	A	A
Foreman's experience = 1	P	P
Consistency	1	1
Raw coverage	0.4	0.8
Unique coverage	0.4	0.8
Cases	P10, P14, P16, P20	P10, P14,P16, P20
Solution coverage	0.4	0.8
Solution consistency	1	1

Note: P = condition present; A = condition absent; LPS implementation (1:Yes); Experience of the project manager with similar facilities (1:>=15 years); Experience of the foreman with similar facilities (1:>=15 years).

tive management and leadership competency play crucial roles in a project's success. Although previous studies have stated that many projects fail mainly because of the project manager's role [74], other stakeholders, such as the construction site foreman, can also significantly influence the project's outcomes [6,76,77,79]. Authors such as Koskela [4], Skinnarland [11], and Fernandez-Solis et al. [6] have stated that the role of the foreman is essential to ensure predictable workflows downstream, guarantee mutual responsibility among project participants, and guide work crews by teaching them how to plan their work more effectively. Additionally, Ballard [10] stated that foremen must be involved in production control systems and the selection of subcontractors. However, foremen with low levels of construction management experience can negatively affect project planning, scheduling, and communication. In an LPS context, Fernandez-Solis et al. [6] and Tayeh et al. [83] highlighted that the technical skills of the workforce can help organizations to more easily implement LPS [6,50]. LPS implementation can help to reduce construction time but can also increase profits, improve safety, and increase the overall quality of the project [11,84].

5. Conclusions

This study analyzes how LPS implementation and the construction management experience of the project manager and the construction site foreman individually influence project management's success, getting minimum time and cost deviations. This work investigates 20 Spanish new-build single-family house projects with similar characteristics. A combined quantitative and qualitative analysis was performed. The quantitative analysis uses the Mann–Whitney *U* test to assess the individual influence of each independent variable in term of cost and time deviations. The results show that the construction site foreman's experience influences cost deviation, whereas LPS implementation significantly influences time deviation.

The qualitative analysis is based on the QCA method. This approach allows the influence of variables' interaction to be analyzed in terms of project management outcomes. Two QCAs are performed to identify the necessary and sufficient conditions to achieve cost and time deviations below 10%. The experience of the construction site foreman is a necessary condition to maintain cost deviations below 10%; however, to achieve a time deviation under 10%, only LPS implementation was found to be significant as a necessary condition. Among the studied projects, one combination of conditions was found to be sufficient to minimize both cost and time deviations: implementing LPS and having a project foreman with more than 15 years of construction management experience. This combination was found to be empirically significant to guarantee time deviations below 10%. Additionally, the project manager's construction management experience was found to not significantly influence cost and time deviations; the effect of this variable was overshadowed by the foreman's experience and LPS implementation.

The contribution of this study to the field of construction project management literature is the provision of empirical evidence about both the individual influence and combinations of the following conditions: project manager's experience, construction site foreman's experience, and LPS implementation. These factors are analyzed in terms of controlling cost and time deviations of new-build single-family house projects. The 20 studied cases in this work represent various combinations of these conditions and can be used as a reference by contractors. A practical implication of this study is that contractors should select an appropriate foreman with experience in construction management to ensure cost deviations remain below 10%. Additionally, implementing LPS with a foreman with extensive construction management experience can keep project time deviations below 10%.

Furthermore, this research contributes to understanding success in project management and highlights that requiring a project manager with extensive experience in construction management is empirically insignificant for achieving the project's goals. However, implementing LPS and requiring a foreman with extensive experience in construction management can significantly influence the project's outcomes.

In terms of this study's limitations, a systematic analysis of a relatively small sample of 20 construction projects was performed; therefore, the results must not be interpreted as statistically validated evidence. The results of this work should be considered as hypotheses to be tested and validated in future studies with larger sample sizes that permit deeper statistical analyses. In addition, this research focuses only on the Spanish single-family house subsector. These results provide an important perspective of one of the largest construction markets in Spain; however, this focus also limits the generalizability of the findings. The influence of additional conditions on the success of project management should be analyzed in further qualitative and quantitative research. Furthermore, an international perspective should be studied since different project factors may influence the success of project management in other countries. QCA should also be implemented to analyze other performance metrics such as quality, productivity, safety, etc. In addition, studying a significant sample of cases would allow the level of importance of different project management characteristics on a project's success to be analyzed.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Funding for open access charge: CRUE - Universitat Politècnica de València.

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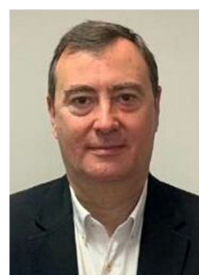

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