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LEAN TOOLS PROPOSAL TO MITIGATE DELAYS AND COST OVERRUNS IN CONSTRUCTION PROJECTS

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ABSTRACT

Construction projects are carried out under the triple constraint of cost, time, and scope, as stated in the project management literature. However, time and cost deviations in the construction industry are frequent, and their magnitude in many cases is considerable, generating harmful consequences. This paper developed a literature review to examine 33 research papers published since 1988 in the Web of Science database to identify the main factors causing these deviations, demonstrating that there is no evidence that it is a problem exclusive from a region, country, or project type. A list of 74 factors has been identified from the top ten reported in each paper. The factors were grouped, taking into account their origin. Simultaneously through literature review, tools, methods, and approaches of Lean Construction were also identified, and after an analysis of its nature, these tools were assigned to the previously identified factors considering the possibilities to mitigate their effects. For more than 88% of the identified factors, a Lean tool, method, or approach was identified, demonstrating that both topics are related, and the body of literature developed must be integrated.

KEYWORDS

Delays, Cost overruns, Construction projects, Lean tools, Lean plan

INTRODUCTION

Delays and cost escalations in construction projects are problems that have been approached by many researchers through time, developing a significant body of literature.

This paper presents a literature review that examines 33 research papers published from 1988 until 2018 in the Web of Science database demonstrating that these problems are still prevalent. A substantial number of studies worldwide have addressed this topic

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to reveal the magnitude. It has been established that 9 of 10 transport infrastructure projects around the world present this deviation (Flyvbjerg et al. 2002). In Australia, a study revealed a mean cost overrun of 12.22%, including civil engineering and construction projects (Love et al. 2013). More recently in Colombia, it was reported that public infrastructure projects had experienced delays as high as 342% and cost overruns as high as 110% (Vallejo-Borda et al. 2015). A significant body of the literature have been developed, but there is a need to summarize and aggregate the literature to find out the actual status of the field and to propose tools, methods and approaches to mitigate the effects.

In this paper, a Lean Implementation Plan is proposed to identify Lean tools, methods, and approaches that allow mitigation of the factors causing delays and cost overruns in construction projects. These Lean tools have been extracted through a literature review, according to the State of Art and Practice (Arroyo et al. 2019; Castiblanco et al. 2019; Farzad and Cameron 2019; Giménez et al. 2019; Gómez-Sánchez et al. 2019; Hackler et al. 2019; Ryan et al. 2019; Salazar et al. 2019; Skaar 2019; Taggart et al. 2019).

RESEARCH METHODOLOGY

This section describes the research methodology developed by the authors of this document. The research procedure consisted of: (1) Initial literature search about deviations and cost overruns in construction projects; (2) Perform an in-depth qualitative analysis of the documents; (3) Identification of 74 relevant factors; (4) Classification of the 74 factors in 6 groups; (5) Search for the most used Lean Construction tools; (6) Short definition of each selected tool; (7) Assignment of a specific Lean tool to mitigate each of the factors (8) Proposal for an implementation plan.

IDENTIFICATION OF FACTORS CAUSING DELAYS AND COST OVERRUNS IN CONSTRUCTION PROJECTS

To obtain an overall picture of the research problem, a systematic and extensive search was conducted. The objective consisted of gathering peer-reviewed articles related to delays and cost overruns in construction projects from the Web of Science and Scopus databases.

A general search on the Web of Science Core Collection was developed. The search was refined, limiting the category to “Engineering civil” and “Construction building technology.” The search results were refined to include articles in English published in journals with an assigned quartile, reporting factors generating delays, and cost overruns in construction projects around the world. Papers excluded were those focusing on the effects or implications of the research topic. Then, a review of the titles and abstracts for each one of the papers found in the initial search was developed by screening the selected papers. This review verified that the papers met the goal of the research and eliminated those that did not apply. A previous study developed was considered (Gómez-Cabrera et al., 2019).

Then, the data collection included a deep-systematic reading of the selected papers, extracting information like journal, year, country (refers to the country where the projects analyzed in the paper were developed), type of deviation reported (Cost, time or both), type of projects considered (Buildings, Infrastructure, both or not available - NA), and factors reported as generators of cost and time overruns in construction projects (as included in most of the papers). At this point, the top ten factors were extracted from each

article, although not all articles included at least ten. Seventy-four factors were identified and classified into six groups (see Table 2). The references analyzed in this research included papers from different regions, those are cited according to the number of documents: China (Lo et al. 2006) (Chiu and Lai 2017) (Chan and Kumaraswamy 1996) (Wang et al. 2018), Iran (Fallahnejad 2013) (Derakhshanalavijeh and Teixeira 2017) (Shahsavand et al. 2018), Nigeria, (Okpala and Aniekwu 1988) (Elinwa and Joshua 2001) (Aibinu and Odeyinka 2006), Turkey (Kazaz et al. 2012) (Gunduz et al. 2013) (Gunduz et al. 2015), Australia (Doloi 2013) (Creedy et al. 2010), India (Iyer and Jha 2006) (Doloi et al. 2012), Vietnam (Le-Hoai et al. 2008) (Kim et al. 2017), Benin (Akogbe et al. 2013), Burkina Faso (Bagaya and Song 2016), Cambodia (Santoso and Soeng 2016), Denamrk (Larsen et al. 2016), Egypt (Abd El-Razek et al. 2008), Malawi (Kamanga and Steyn 2013), Pakistan (Batool and Abbas 2017), Palestine (Mahamid et al. 2012), Saudi Arabia (Assaf et al. 1995), Tanzania (Sambasivan et al. 2017), United Arab Emirates (Mpofu et al. 2017), Zambia (Kaliba et al. 2009), and other including diferent countries (Ahsan and Gunawan 2010) (Ruqaishi and Bashir 2015).

Figure 1 shows the number of publications per deviation reported and project type. In Figure 1-left, the type of deviation reported in the articles is included, TI: Time deviation, CO: Cost deviation, and CO/TI: Both. Figure 1-right consists of the type of project included: BU-Buildings, IN- Infrastructure, BU/IN - for both and NA - Not Available.

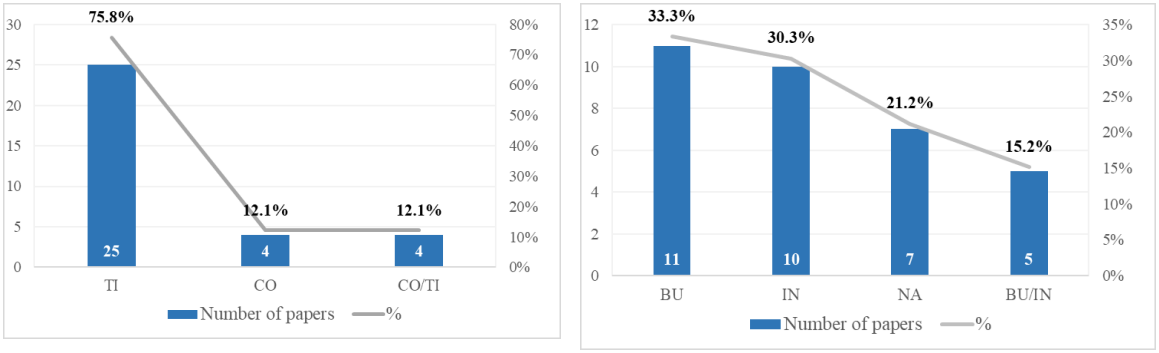

Figure 1: Number of publications per deviation reported and project type

LEAN IMPLEMENTATION PROPOSAL

Following the problems mentioned above and the consequences they imply for the construction industry worldwide, the authors offer a Lean Implementation Plan (LIP). This plan is based on the study of the state of the art and practice, proposing to each factor a particular Lean tool, method, or approach that can mitigate its effects.

PHASES OF THE PROPOSAL

The authors propose 5 phases to implement the Lean Plan. First, the project where the intervention will be carried out must be known and characterized; The next step is to make a diagnosis using different KPI´s, to establish a baseline; Then, the Lean tools, methods, or approaches are selected (according to the problems detected in the initial diagnosis); Subsequently, the tools, methods, or approaches are applied in each particular case; Finally, evaluate and start a process of continuous improvement, see Figure 2.

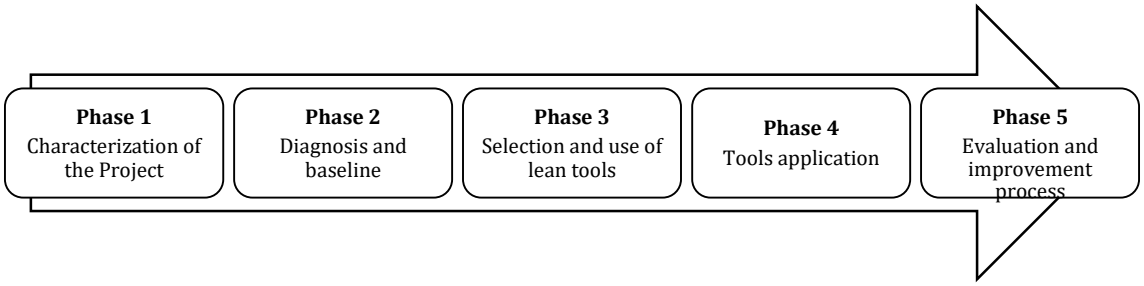

Figure 2: Phases of Lean Implementation Plan

LEAN TOOLS PROPOSAL

According to the State of Art and Practice, the authors selected the main tools, methods, and approaches of Lean Construction that can mitigate the factors that generate delays and cost increases in construction projects. See Table 1.

Table 1: Main Lean Construction Tools/Methods/Approaches

Tools	Short Definition	References
Last Planner® System (LPS)	"System for project production planning and control, aimed at creating a workflow that achieves reliable execution, developed by Glenn Ballard and Greg Howell. LPS® is the collaborative, commitment-based planning system that integrates should-can-will-did planning: pull planning, make-ready look-ahead planning with constraint analysis, weekly work planning based upon reliable promises, and learning based upon analysis of PPC and Reasons for Variance."	(Lean Construction Institute 2017)
Building Information Models (BIM)	"The process of generating and managing building data during the life cycle of a building. BIM uses three-dimensional (3D), real-time, dynamic building modeling software. BIM includes building geometry, spatial relationships, geographic information, and quantities and properties of building components. BIM can include four-dimensional or more (4D, 5D, etc.)…BIM provides the platform for simultaneous conversations related to the design of the "product" and its delivery process"	(Lean Construction Institute 2017)
Visual Management (VM)	"Placing tools, parts, production activities, plans, schedules, measures and performance indicators in plain view, This assures that the status of the system can be understood at a glance by everyone involved and actions taken locally in support of system objectives."	(Lean Construction Institute 2017)
Value Stream Mapping (VSM)	"VSM is a paper and pen tool where a map of the complete process is drawn out with a set of standardized icons, introduced by Rother and Shook (1998). With a map of the complete process, it is easier to analyze and identify any weaknesses or waste sources. Once these are identified, changes are proposed and implemented and the new process is evaluated"	(Deffense and Cachadinha 2011)
Integrated Project Delivery (IPD)	"A project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of the project, from early design through project handover"	(Lean Construction Institute 2017)
Target Value Design (TVD)	"TVD views AEC (Architecture, Engineering and Construction) as a complex system, which includes the project definition, design and construction stages. TVD transforms the current design practices upside down because the costs determine the design instead of the design determining the costs"	(Miron et al. 2015)
Linguistic Action Perspective	"Linguistic Action Perspective was developed by F. Flores (2015) and it is basically an application of Speech Act Theory to organizational	(Salazar et al. 2018)

(LAP)	management. That conversations do not simply precede action, but rather constitute actions themselves through the commitments that emerge… Every conversation for action includes four basic speech acts: 1) request or offer, 2) promise or acceptance, 3) declaration of compliance and 4) declaration of satisfaction"	(Salazar et al. 2019)
Choosing by Advantages (CBA)	"CBA is a tested and effective sound decision-making system developed by Jim Suhr (1999) for determining the best decision by looking at the advantages of each option"	(Lean Construction Institute 2017)
Gemba Walk	"Gemba is the Japanese word for "actual place." This concept was developed in the Lean manufacturing paradigm into the practice of Gemba walks. It is essential to understand the importance of "go and see" for the construction process"	(Taggart et al. 2019)
5S	"The 5S's are of Japanese origin and are distributed in five actions aimed at organization and standardization of work. The 5S's of this methodology are Seiri (Sorting), Seiton (Stabilize), Seiso (Systematic Cleaning), Seiketsu (Standardizing), and Shitsuke (Sustaining)"	(Deffense and Cachadinha 2011)
Just in Time (JIT)	"A system for producing or delivering the right amount of parts or product at the time it is needed for production"	(Lean Construction Institute 2017)
Kanban	"Japanese term meaning "a signboard." A communication tool used in JIT production systems. The signal tells workers to pull parts or refill material to a certain quantity used in production"	(Lean Construction Institute 2017)
A3 Report	"A one-page report prepared on a single 11 x 17 sheet of paper that adheres to the discipline of PDCA thinking as applied to collaborative problem solving, strategy development or reporting. The A3 includes the background, problem statement, analysis, proposed actions, and the expected results"	(Lean Construction Institute 2017)
Set-Based Design (SBD)	"A design method whereby sets of alternative solutions to parts of the problem are kept open until their Last Responsible Moment(s), in order to find by means of set intersection the best combination that solves the problem as a whole"	(Lean Construction Institute 2017)
Jidoka	"Concept Japanese, translated as 'autonomation' in English, this form a pillar of the Toyota Production System. Autonomation refers to machines built to detect problems and stop by themselves, so as to "relieve the burden of constantly supervising a machine, and allow [people] to use their talents for more beneficial things (like adding value)" (Liker and Meier 2006 p. 177)	(Tommelein 2008)

Then, for each one of the identified factors in the first stage, a main Lean construction tool, method, or approach was assigned, considering the possibilities to mitigate their impacts. The results are included in Table 2.

Table 2: Lean Construction Tools/Methods/Approaches assigned to factors

	Group	Factors (problems)	Main Lean tool
1	Design	Design changes	Set-Based Design (SBD)
2		Design errors	Set-Based Design (SBD)
3		Preparation/ Approval of designs	Building Information Models (BIM)
4		Extent of completion of pre contract design	Set-Based Design (SBD)
5	Project	Contractor´s financial problems	--
6		Nonperformance / problems subcontractors	Linguistic Action Perspective (LAP)
7		Subcontractor´s financial problems	--
8		Low speed of decision making	Choosing by Advantages (CBA)
9		Poor planning and scheduling	Last Planner® System (LPS)
10		Poor site management/ supervision	Gemba Walk

11		Poor management of contractors' schedules	Last Planner® System (LPS)
12		Lack of coordination/communication/integration	Linguistic Action Perspective (LAP)
13		Low level of professional skills	--
14		Complexity of works	Value Stream Mapping (VSM)
15		Poor technical performance	Jidoka
16		Poor project management assistance	Visual Management (VM)
17		Delay in performing inspection and testing	Jidoka
18		Improper control over site resource allocations	5s
19		Methods/techniques of construction	Value Stream Mapping (VSM)
20		Contractor's deficiencies in planning and scheduling at tender stage	Last Planner® System (LPS)
21		Shortage of contractors	Integrated Project Delivery (IPD)
22		Consultant recruitment delay	Last Planner® System (LPS)
23		Project staff hiring delay	Last Planner® System (LPS)
24		Tendency to pass on the blame to others	Linguistic Action Perspective (LAP)
25		Conflict between project parties	Integrated Project Delivery (IPD)
26		Resumption/accommodation works	Building Information Models (BIM)
27		Project administration cost increase	Integrated Project Delivery (IPD)
28		Remote location costs	--
29		Quantity increased measure	Building Information Models (BIM)
30		Poor contract management	Integrated Project Delivery (IPD)
31		Schedule delays	Last Planner® System (LPS)
32		Contractor risk´s management	Integrated Project Delivery (IPD)
33	External aspects	Environmental impacts mitigation	Choosing by Advantages (CBA)
34		Weather	A3 Report
35		Natural calamities	A3 Report
36		Unforeseen ground conditions	A3 Report
37		Works in conflict with existing utilities	Building Information Models (BIM)
38	Owner management	Financial difficulties by the owner	Target Value Design (TVD)
39		Errors in bidding and award	Integrated Project Delivery (IPD)
40		Delays in decision making	Choosing by Advantages (CBA)
41		Inexperienced contractor/ consultant	Building Information Models (BIM)
42		Insufficient feasibility studies and survey before investment	Set-Based Design (SBD)
43		Duration of contract period	Target Value Design (TVD)
44		Burocracy/ Inneficient internal processes	Value Stream Mapping (VSM)
45		Delays in progress payment	Last Planner® System (LPS)
46		Change orders/ scope change	Set-Based Design (SBD)
47		Land acquisition delay/ Late site delivery	Last Planner® System (LPS)
48		Ambiguous/errors contract information	Integrated Project Delivery (IPD)

49		Partial payments during construction	Integrated Project Delivery (IPD)
50		Non utilization of professional construction/contractual management	--
51		Underestimation of time for completion	Last Planner® System (LPS)
52		Underestimation of cost projects	Target Value Design (TVD)
53		Inadequate definition of substantial completion	Target Value Design (TVD)
54		Noncompliance with conditions of contract	Building Information Models (BIM)
55		Inadequate cost estimating approach	Target Value Design (TVD)
56	Resources	Shortage of labors	Kanban
57		Unqualified work force/ productivity	Gemba Walk
58		Shortage of materials	Just in Time (JIT)
59		Delay in material to be supplied by the owner	Just in Time (JIT)
60		Material procurement/delays	Just in Time (JIT)
61		Delay in material procurement (by the contractor)	Just in Time (JIT)
62		Delay in approving sample materials	Last Planner® System (LPS)
63		Poor interaction with vendors in the engineering and procurement stages	Target Value Design (TVD)
64		Shortage of fuel	Just in Time (JIT)
65		Shortage of foreign currency	Just in Time (JIT)
66		Poor quality of equipment	Choosing by Advantages (CBA)
67		Shortage of equipment	Just in Time (JIT)
68	Government / society	Government pressures/ policies	--
69		Strikes	Linguistic Action Perspective (LAP)
70		Government procedural delay/ permissions	Last Planner® System (LPS)
71		Society concerns	Linguistic Action Perspective (LAP)
72		Public Order Situation	--
73		Political situation	--
74		Inflation/ Economic problems	--

Finally, the authors emphasize that each factor can be mitigated by more than one Lean tool. Therefore, Table 3 shows the factors that could be mitigated by each selected Lean tool, method, or approach.

Table 3: Lean Construction Tools features

Lean Tools, Methods & Approaches	Time and cost deviations factor
BIM	1, 2, 3, 8, 9, 10, 11, 12, 14, 16, 19, 20, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 48, 51, 52, 53, 54, 55, 60, 61, 62, 63, 70
Set-Based Design (SBD)	1, 2, 3, 4, 9, 11, 12, 14, 16, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 51, 52, 53, 54, 55, 60, 61, 62, 63, 70
Linguistic Action Perspective (LAP)	6, 9, 12, 18, 24, 25, 26, 27, 31, 40, 41, 44, 45, 46, 53, 60, 61, 62, 63, 69, 70, 71
Choosing by Advantages (CBA)	2, 3, 8, 9, 12, 14, 18, 19, 20, 21, 22, 23, 24, 25, 29, 30, 31, 32, 33, 36, 37, 38, 39, 40, 41, 42, 43, 44, 46, 47, 48, 51, 52, 53, 54, 55, 62, 63, 64, 65, 66, 70, 71
Last Planner® System (LPS)	6, 9, 10, 11, 12, 14, 18, 20, 21, 22, 23, 24, 25, 26, 27, 30, 31, 34, 35, 40, 43, 44, 45, 46, 47, 51, 56, 58, 59, 60, 61, 62, 64, 66, 67, 70
Gemba Walk	9, 10, 12, 14, 17, 18, 19, 25, 26, 31, 34, 35, 40, 45, 46, 56, 57, 58, 59, 60, 61, 62, 63, 66, 67
Jidoka	10, 14, 15, 17, 18, 20, 29, 30, 31, 32, 33, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 48, 51, 52, 55, 62, 63, 70
Visual Management (VM)	1, 2, 3, 8, 9, 12, 14, 16, 18, 19, 20, 24, 26, 29, 30, 31, 32, 33, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 51, 52, 53, 54, 55, 59, 60, 61, 62, 63, 67, 70
Integrated Project Delivery (IPD)	1, 2, 3, 8, 9, 11, 12, 14, 16, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 51, 52, 53, 54, 55, 62, 63, 70
A3 Report	1, 2, 3, 17, 18, 34, 35, 36, 38, 40, 42, 44, 56
Target Value Design (TVD)	1, 2, 3, 9, 19, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 38, 39, 40, 41, 42, 43, 44, 45, 46, 48, 49, 51, 52, 53, 54, 55, 64, 65, 70
Just in Time (JIT)	21, 22, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67

CONCLUSIONS

In this research, a literature review has been developed in two topics, factors causing time and cost deviations and lean tools, methods, and approaches applicable to construction projects. Although it has been focused on the Web of Science database, building and infrastructure projects have been included in the first stage to have global information.

The analysis developed in this research allowed assigning a lean mitigation tool, method, or approach for 87.84% of the factors. The factors on which it was not possible to assign lean tools, methods, or approaches corresponded to those related to financial aspects, to aspects of professional and workers training and factors like political or social situation, problems with inflation. On the other hand, there are factors that can be mitigated with two or more tools, for example, the meteorological factor; it can be considered a constraint in the Last Planner System and then determine the best solution through an A3 report.

The literature review allowed developing an in-depth analysis of the research related to factors causing delays and cost overruns in construction projects and lean tools, methods, and approaches applicable to the construction industry. Both have been a subject of interest among authors who have developed an important body of literature, and for this reason, it is proposed the integration. Future research may focus on demonstrating the effectiveness of the lean tools, methods, and approaches discussed in this article.

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