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A Lean Approach to Minimize Cost Overruns in Transportation Projects: A Pre-construction Perspective

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Abstract

Question: What lean approaches are more suitable for improving pre-construction processes, which, if not performed effectively, are likely to lead to cost overruns in the construction of transportation projects?

Purpose: The purpose of this research is twofold. First, to identify what main pre-construction processes have the potential to lead to cost overruns in construction if not conducted effectively. Two, to identify what lean techniques might be more suitable to improve those processes.

Research Method: This research followed a two-stage methodology. First, the authors conducted a systematic literature review and a focus group to identify and validate the pre-construction processes to be analyzed in the second stage. Second, the authors completed a two-round Delphi Survey to identify and rank the most suitable lean techniques for improving the processes identified in Stage 1.

Findings: The authors found "Risk Identification and Assessment" and "Design Interdisciplinary Reviews" to be the two most relevant pre-construction processes that, if not conducted effectively, might lead to cost overruns in construction. To improve those processes, Integrated Project Delivery (IPD) and Target Value Design (TVD) were found to be suitable for improving both processes. Last Planner System (LPS®) and Building Information Modelling (BIM) were identified for improving "Risk Identification and Assessment" and "Interdisciplinary Design Reviews," respectively. All the lean approaches identified are based on team collaboration.

Limitations: The results of this research are based on experts' opinions. Further research should test the effectiveness of using these lean techniques and their impact on minimizing cost overruns in construction.

Implications: The results from this research support the use of collaborative approaches in

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developing preconstruction processes to minimize construction cost overruns.
Value for authors: The lean approaches proposed as a result of this research might inspire owners and practitioners to boost collaboration within and across pre-construction processes.
Keywords: Transportation Projects, Cost Overruns, Delphi Survey, Pre-construction
Paper type: Technical Note

Introduction

Large-scale transportation projects have far-reaching effects on the economy and communities. Community vitality, economic development, and transportation efficiency are all boosted by these kinds of projects (Heet et al. 2020). Nevertheless, developing a transportation infrastructure efficiently in terms of time and cost is challenging (Adafin et al. 2016). Previous research has examined reasons leading to cost overruns in transportation projects (Love et al. 2016, Bordat et al. 2004, and Flyvbjerg et al. 2004) without providing specific tools on how these reasons could be reduced or eliminated. Other researchers have highlighted the importance of allocating more resources in the pre-construction stages to increase the success rate of achieving the planned goals, including completing the project on budget (George et al. 2008, Hanna and Skiffington 2010, Liu et al. 2013, Hwang and Ho 2012).

Lean Construction, on the other hand, refers to the application of lean thinking to the delivery of capital projects in the Architecture-Engineering-Construction (AEC) industry (Tommelein 2015). Lean Construction seeks design and construction that provide the best value to the owner by (1) achieving an early common understanding of the owner's needs across all project members, (2) Doing the right things the first time in all phases of the project (Abdelhamid and Copeland 2022). Lean Construction aims to maximize value and reduce waste through systematic, synergistic, and continuously improved design and building processes and flows (Lean Construction Institute 2024). As a result, many lean techniques have been developed for design and engineering, planning and control, construction and site management, and health and safety management (Babalola et al. 2019).

Highway Agency (HA), an executive agency of the UK Department of Transport, for example, has successfully applied Lean techniques as a driver to deliver continuous improvement in the agency (Fullalove 2013). Even though several researchers have explored lean tools in construction projects in general (Villanueva et al. 2022, Watfa and Sawalha 2021), few research focus on the use of lean in transportation projects.

Thus, this research focuses on the pre-construction stage of transportation projects and has two main objectives: first, to identify what processes, if not conducted effectively, can lead to cost overruns, and second, to determine what lean techniques might be more suitable to improve those processes. The paper is structured as follows: methodology, results and discussion, conclusions, acknowledgments, and references

Methodology

This research aims to identify and explore which Lean Construction techniques can be applied in pre-construction processes to minimize cost overruns in the construction of

transportation projects. To this end, the research follows a two-stage approach. Stage 1 aims to identify two relevant pre-construction processes that, if they are not developed effectively, can lead to cost overruns in construction. Stage 2 aims to determine what lean techniques are more suitable to improve the development of the processes identified in Stage 1 (Table 1).

Table 1: Research Methodology

	Objective	Research Methods
Stage 1	Identify main pre-construction processes with a relevant impact on cost overruns in transportation projects	1.1 Systematic literature review 1.2 Focus group
Stage 2	Identify and rank the most suitable techniques to improve the processes identified in Stage 1	2. Delphi survey

Stage 1 Identification of pre-construction processes

Stage 1 includes two steps. First a systematic literature review. Second, a focus group. The systematic literature review aimed to identify the main reasons leading to cost overruns in the domain of transportation projects. From the list of reasons identified in this search, the researcher filtered the reasons that relate to pre-construction processes, which are the focus of this research. These selected reasons were considered in the step 2 focus group, with the objective of ranking them and selecting the most relevant ones to be further analyzed in stage 2. In this research, "the most relevant ones" means the reasons that have a major impact on cost overruns in the construction phase.

Step 1.1. Systematic literature review

A systematic literature review is an established process with several steps that can assist the researcher in organizing the selection and reporting of literature articles (Ardito et al.2015). As an essential feature of academic research, a systematic review is a planned and structured method to review relevant published academic work to critically identify and evaluate the literature (Friday et al. 2018). The systematic literature review includes planning, conducting, and reporting. It includes gathering a set of publications in the area under study followed by a careful examination of the published works to identify recurring themes (Xiao and Watson 2019).

As the purpose of the systematic literature review in this research was to identify the reasons that could lead to cost overruns in transportation projects, to conduct a systematic literature review, the researcher conducted a literature search by developing a comprehensive search strategy using relevant keywords and a database. The researcher used the ASCE Database. The direction of the inquiry was determined by using a

combination of the keywords “cost overruns," "transportation construction projects," "cost overruns cause,” and “preconstruction.”

The selection of the relevant literature was undertaken by a thorough review of titles, abstracts, and keywords. The objective was to discern and select the most beneficial studies, articles, or papers that strongly resonate with the defined research objectives which was to find the reasons for cost overruns in the transportation projects.

Step 1.2. Focus group

A focus group is a qualitative research method used to gather insights and opinions from a diverse group of individuals about a specific topic or set of topics (Leung et al. 2014). It involves bringing together a small group of participants who share certain characteristics or experiences relevant to the research question. Through guided discussions facilitated by a researcher, focus groups aim to delve into participants, opinions, and perceptions, providing a nuanced understanding of their viewpoints (Harvey and Holmes 2012).

The purpose of the focus group in this research was twofold. First, to validate the pre-construction processes associated with the cost overruns identified in the systematic literature review (step 1.1). Second, to rank the pre-construction processes based on their ability to have a major impact in having cost overruns if not conducted effectively.

The focus group was set up on September 15th, 2023, at 10:00 am. Participants were selected based on their experience in heavy civil construction. The heavy civil companies Kiewit and DeSilva Gates were invited to participate and representatives from them attended a virtual meeting via Zoom.

The researcher delivered a 10-minute presentation to brief the professionals invited on the overall goals of the study and the anticipated outcomes of the focus group. The results of the literature review and associated pre-construction processes were summarized in a PDF document that the researcher also provided to support the discussion. Participants were asked to identify and rank what pre-construction processes had a major influence, leading to cost overruns if not conducted adequately.

Stage 2 Identification of the most suitable lean techniques

The objective of stage 2 was to identify the three most suitable lean techniques to improve the pre-construction processes identified in stage 1. To this end, gathering Lean experts’ opinion through a Delphi survey was found to be the research method that best aligned with the objectives.

The Delphi method is a systematic and interactive research technique that collects opinions from a panel of unbiased experts on a specific topic. Participants are requested to engage in multiple rounds of structured surveys after being selected based on predetermined criteria. After each round, the facilitator adds an anonymous summary of the experts' answers from the previous survey to the next one. Participants are urged to reconsider their initial answers and carefully examine the anonymous viewpoints of the other panelists in each subsequent round. The primary goals of this process are to reach a consensus among the group regarding the accurate value and to minimize variability in responses. Once a specific condition, such as reaching a certain number of rounds or achieving consensus, is met, the process concludes. The outcomes are determined by

statistically aggregating the responses from the last round (Hallowell and Gambatese 2010).

The Delphi survey has been suggested when there is a limitation in the literature on a particular topic, when experts possess knowledge in different disciplines, or when respondents need to reach a consensus in an unrestricted setting (Pamidimukkala and Kermanshachi 2023). This research is developed at the intersection of transportation projects and Lean Construction, where little research has been conducted. It also requires experts with knowledge of different disciplines, such as Lean Construction, transportation projects, and project management.

In the design of the Delphi survey, the following aspects are relevant to ensure sound results: selection of the panel experts, questionnaire design, anonymity of responses, feedback between rounds, number of rounds, and interpretation and reporting results (Table 2).

Table 2: Delphi Survey Design Criteria

Design criteria	Description
Selection of Panel Experts	Experts were chosen based on their knowledge, experience, and level of expertise in the field of Lean Construction and Lean in Public Sector (See experts evaluation criteria in Table 3)

Questionnaire Design	First round:
	• Six questions, three per pre-construction process:
	• Pre-construction process A:
	  ○ Q1. Rank a predetermined list of Lean techniques
	  ○ Q2. For the top three lean techniques, explain the reason behind the ranking
	  ○ Q3. Provide additional lean techniques that could be suitable for the process analyzed.
	• Pre-construction process B:
	  ○ Same Q1, Q2, and Q3.
	Second/Third rounds
	• Provide a summary of the previous round.
	• Four questions, two per pre-construction process:
	  ○ Q1. Rank (again) a predetermined list of Lean techniques.
	  ○ Q2. For the top three lean techniques, explain the reason behind the ranking

Anonymity of Responses	The software eDelphi.org was used to ensure that experts did not know each other or their responses.
Feedback between rounds	The feedback provided included the consolidated results of all the experts and a summary of the reasons why each expert rated in the way they did.

Design criteria	Description
Number of rounds	Between 1-3 or once a consensus is reached. Consensus is defined as having more than 50% of the experts agreed on the three techniques being in 1st, 2nd and 3rd place.
Interpretation and reporting results	This research did not look for a unique answer (e.g., "This lean technique is the best for preconstruction process A"). The aim of the research was to identify a range of lean techniques that could be suitable for improving the processes under analysis. Thus, the researchers considered that consensus was reached when more than 50% of the experts agreed on the three top-ranked techniques, regardless of whether one considers one technique to be the first one and another the third one. Interpretation and reporting of the results are shown in section "Results & Discussion"

The results of this research are based on an expert's opinion. Therefore, selecting experts is a fundamental piece of research design. The authors aimed to identify experts in Lean. A professional or academic was identified as an expert if he/she/they met the criteria included in Table 3. These criteria were suggested by Hallowell and Gambatese (2010), who provided in their article best practices to conduct academically sound Delphi Method research.

Table 3: Experts Evaluation Criteria

Experts/ Evaluation criteria	>5 years' experience (3 points)	Author Peer Review article (3 points)	Book Author (4 points)	Lean Conference Presenter (2 points)	Member of Lean Related Committee (2 points)	Faculty Member (3 points)	Education (Points: BS:3, MS: 3. Ph.D.:4)	Total
Expert 1	3	3	4	2	2	3	10	27
Expert 2	3	3	0	2	2	3	10	23
Expert 3	3	3	0	2	2	2	10	22
Expert 4	3	3	0	2	2	2	3	15
Expert 5	3	3	0	2	0	3	10	21
Expert 6	3	3	0	2	0	3	10	21
Expert 7	3	0	2	2	2	2	3	14
Expert 8	3	0	2	2	2	0	3	12

Results & Discussion

This section summarizes the results obtained in each of the stages defined in the methodology.

Identification of main pre-construction processes leading to cost overruns in construction

During the initial stage of the systematic literature review, the researcher executed a comprehensive database search, yielding 218 scholarly articles. The researcher then applied predetermined inclusion and exclusion criteria to this initial set. This process resulted in the retention of 120 records aligned with the theme of cost overruns in transportation projects. Subsequently, a critical appraisal of the abstracts was undertaken to evaluate the relevance and scope of the studies in relation to the research objectives. This assessment further refined the corpus to 50 records from which the most frequently mentioned reasons for cost overruns were identified (Table 4).

Table 4 Reasons for cost overruns found in literature and related pre-construction processes.

Reasons found through systematic literature review	# articles where the reason was identified	Related Pre-Construction process
Design Changes	6	Design management
Change in scope of work	4	Scope management
Design errors	4	Design management
Unforeseen site conditions	4	Risk identification and assessment
Inaccurate site investigations	4	Risk identification and assessment
Awarding the contract to the lowest bidder	4	Project delivery method
Inaccurate cost estimates	3	Cost Management
Change orders	3	Cost and Scope Management
Poor site planning	3	Site & Operations management

The list of related pre-construction processes was the basis for the discussion in the focus group, where participants were asked to identify and rank what pre-construction processes had a major influence on, leading to cost overruns if not conducted adequately. The results of the discussion lead to two pre-construction processes: (1) Risk Identification and Assessment and (2) Interdisciplinary design reviews.

Identification of the most suitable lean techniques

The first round of the Delphi Survey was sent to the group of panel members by e-mail in March 2024. The invitation email explained the aim of the research, and the

experts were informed that there would be several rounds until a consensus was reached. The purpose of the first Delphi round was to identify and rank the most suitable lean technique to improve the pre-construction process R*isk Identification and Assessment*, as well as the process of *interdisciplinary reviews*.

Lean techniques to improve the process of *Risk Identification and Assessment*

This section includes the results obtained in the different rounds conducted. Two (2) rounds were needed to reach a consensus.

Round 1

Table 5 shows the results obtained for the process of *Risk Identification and Assessment*. Green cells highlight the number of times that each technique was ranked as first. For example, Integrated Project Delivery (IPD) was ranked by four (4) experts out of eight (8) as the first most suitable technique to address the process of *Risk Identification and Assessment*. Further, half of the experts agreed that target value design (TVD) and Last Planner are the second most suitable techniques to improve this process.

Table 5: Round 1. Lean techniques rankings for the process of Risk Identification and Assessment

Techniques	Ranks given to each technique by each expert*							
Integrated Project Delivery	1	1	1	1	2	2	6	7
Target Value Design	1	1	2	2	4	4	5	6
Last Planner	1	3	3	4	5	5	7	8
BIM	3	3	3	4	5	7	9	11
Visual Management	1	2	2	5	6	7	7	9
CBA	3	4	5	5	7	10	10	11
A3 report	2	6	6	6	7	7	8	10
Value Stream Mapping	2	3	5	7	8	8	8	9
Just in Time	6	8	8	9	9	10	11	11
Continuous improvement	4	6	8	9	9	10	10	11
5S Lean	3	4	9	10	10	11	11	11

*Ranks given by eight (8) experts

In addition to the ranking, the experts were asked to provide their thoughts about additional lean techniques that could be used in this task. Experts' comments strongly promote the importance of continuous stakeholder engagement using a range of tools including "Takeaways," "Plus-Delta" charts, pulse reports, and Daily Huddles. Moreover, it is advisable to appoint a Lean Champion to ensure efficient management of processes and to ensure that all stakeholders agree.

A comprehensive compilation of lean tools was provided, including lean techniques such as Andon, Fishbone diagrams, Control Charts, Kanban, Six Sigma, and Scrum. These tools aim to improve efficiency, enhance problem-solving abilities, and standardize processes in project management frameworks. Experts' comments also underscore the crucial significance of team composition in risk assessment, emphasizing the necessity of diverse perspectives and experiences. This involves incorporating individuals with cautious

perspectives as well as those who are more focused on finding solutions while also maintaining a balance between optimism and pessimism in strategic planning. Furthermore, the expert comments explore the incorporation of lean tools in lean environments, specifically within frameworks such as Integrated Project Delivery (IPD) and Target Value Design (TVD). Experts recommend employing risk identification workshops, project checklists, and flow diagrams as efficient approaches for risk management. The discussion encompasses the practical incorporation of basic tools into contracts, demonstrating how Design-Build Institute of America and IPD contracts can employ these tools to bolster and formalize lean processes. In summary, Experts provides a strong framework for implementing efficient strategies in project management, promoting a methodical yet flexible approach to managing risks and improving project results.

Round 2

The objective of the Delphi 2nd round was to reach a consensus on the three topmost suitable lean techniques. The objective was reached by asking the experts to re-evaluate their ranking in round 1. This re-evaluation process had to be done considering the round 1 summary, provided by the researchers that offered an anonymized summary of the reasons why each expert had ranked the techniques in the way they did in the first place.

The researcher also requested the experts to explain the rationale behind their decision whether the experts changed their original ranking or not so that a better understanding of their decision.

In this second round, the researcher limited the number of techniques that the experts had to rank to six (6). These six (6) were the ones ranked in higher places in round 1. Results show that more than 50% of the experts agree that IPD, Target Value Design, and Last Planner are the top three techniques that could help to improve the process *of Risk Identification and Assessment* (Table 6).

Table 6: Round 2. Lean techniques ranking for the process of *Risk Identification and Assessment*

Techniques	Ranks given to each technique by each expert*					
Integrated Project Delivery	1	1	1	1	1	2
Target Value Design	1	2	2	2	2	2
Last Planner	3	3	3	3	3	4
BIM	3	4	4	4	5	5
Visual Management	4	4	5	5	5	5
CBA	6	6	6	6	6	6

*Ranks given by six (6) experts

The authors acknowledge that techniques identified in the survey cannot be applied directly to the pre-construction risk identification and assessment process. IPD is a project delivery method established by the owner before starting the project. Target Value Design (TVD) is a method to develop the design, and the Last Planner system is commonly used in construction scheduling. However, all these techniques, when used in project development, have the ability to identify and assess risks early in the process and, therefore, minimize cost overruns. These results ultimately suggest that a collaborative approach—such as the one that is at the core of IPD, TVD, and Last Planner—can enhance

the process of Risk Identification and Assessment, no matter the project delivery system used.

Lean techniques to improve the process of *Interdisciplinary Design Reviews*

This section includes the results obtained in the different rounds conducted. Two (2) rounds were needed to reach a consensus.

Round 1

Table 7 shows the results obtained for the process of *Interdisciplinary reviews*. Green cells highlight the number of times each technique was ranked first. For example, Building Information Modelling (BIM) was ranked by three (3) experts out of eight (6) as the first most suitable technique to address the process of *Interdisciplinary Design Reviews*. However, three different experts ranked this technique as third, and two different ones as fifth and eleventh. Thus, there is not a common trend for the techniques' rankings regarding the first, second and third most suitable ones.

Table 7 Round 1. Lean techniques rankings for the *process Interdisciplinary Design Reviews*

Techniques	Ranks given to each technique by each expert*							
BIM	1	1	1	3	3	3	5	11
Integrated Project Delivery	1	1	2	3	3	6	7	7
Target Value Design	1	2	2	4	4	5	7	9
Last Planner	1	2	3	4	4	4	5	10
Visual Management	1	3	3	5	6	6	6	8
A3 Report	5	6	6	7	7	8	9	9
Value Stream Mapping	2	4	5	7	8	8	8	9
CBA	2	2	4	8	9	10	10	11
Just in Time	5	7	8	8	9	9	9	10
Continuous Improvement	2	6	8	9	10	10	10	11
5S Lean	4	7	10	11	11	11	11	11

*Ranks given by eight (8) experts

Round 2

With the objective of narrowing the experts' rankings, in round 2, they were provided with a list of six (6) techniques—the ones that were more frequently ranked in first places in round 1—and also an anonymized summary of the reasons each expert provided in round 1 regarding the reason why they ranked the techniques as they did.

The researcher also requested the experts to explain the rationale behind their decision whether the experts changed their original ranking or not so that a better understanding of their decision.

Table 8 shows the ranking results. In this case, more than 50% of the experts agreed that Building Information Modelling (BIM), IPD, and Target Value Design were the first top lean techniques that can be used to improve the process of *Interdisciplinary Design Reviews*.

The three (3) lean techniques identified highlight the relevance of collaboration in improving interdisciplinary design reviews.

In this second round, two of the experts who participated in the first round did not continue in the second round due to reasons unknown by the researchers. However, this fact did not have a substantial impact on the identification of the three main techniques since this is based on the consensus obtained by all the experts.

Table 8: Round 2. Lean techniques ranking for the process *Interdisciplinary Design Reviews*

Techniques	Ranks given to each technique by each expert*					
BIM	1	1	1	2	2	3
Integrated Project Delivery	1	1	2	2	2	3
Target Value Design	1	2	3	3	3	4
Last Planner	4	4	4	4	5	5
Visual Management	3	4	5	5	5	5
CBA	6	6	6	6	6	6

*Ranks given by six (6) experts

A discussion similar as the one provided for the *Risk Identification and Assessment* process can be applied to the process of *Interdisciplinary Design Reviews*. In this case, Building Information Modelling is added to the list of techniques. One of the key strengths of BIM lies in its visualization capabilities, which significantly improve communication and coordination among all project disciplines and stakeholders. By providing a detailed digital project model, BIM allows everyone, from architects to builders, to see and discuss the same information in real time, leading to better decision-making and a more streamlined project delivery process. Some Delphi experts argue that BIM is not a lean technique, and the authors agree with this opinion. However, BIM is a collaborative tool and, at its core, is aligned with lean principles. Currently, transportation agencies in the US are starting the transition process for implementing BIM in infrastructures (Federal Highway Administration 2021). This will support and help in the interdisciplinary design review to be performed before the construction starts.

Despite the top three lean techniques improving the two pre-construction processes identified, the Delphi survey underscores additional lean tools suggested by the experts that strongly promote continuous stakeholder engagement, such as “Takeaways," "Plus-Delta" charts, pulse reports, and Daily Huddles. Furthermore, lean techniques such as Andon, Fishbone diagrams, Control Charts, Kanban, Six Sigma, and Scrum aim to improve efficiency, enhance problem-solving abilities, and standardize processes in project management frameworks.

Conclusions

This research focused on the pre-construction stage of transportation projects and aimed to achieve two research objectives: first, to identify what processes, if not conducted effectively, can lead to cost overruns, and second, to determine what lean techniques might be more suitable to improve those processes.

After conducting a structured literature review, one focus group, and two rounds of the Delphi Survey, the authors identified *Risk Identification and Assessment* and *Design Interdisciplinary Reviews* as the two most relevant pre-construction processes that, if not conducted effectively, might lead to cost overruns in construction. To improve those processes, Integrated Project Delivery (IPD) and Target Value Design (TVD) were found to be suitable for improving both processes. Last Planner System (LPS®) and Building Information Modelling (BIM) were identified for improving *Risk Identification and Assessment* and *Interdisciplinary Design Reviews*, respectively (Table 9).

Table 9 Three Top Lean Techniques Resulting from the Delphi Survey

Lean Techniques	Pre-Construction Processes	
	Risk Identification and Assessment	Interdisciplinary Design Reviews
Integrated Project Delivery (IPD)	✓	✓
Target Value Design	✓	✓
Last Planner	✓	-
Building Information Modelling	-	✓

The authors acknowledge that the techniques identified in the survey cannot be directly applied to the *risk identification and assessment* or *interdisciplinary review processes*. However, when used in project development, all these techniques can identify and assess risks early in the process and, therefore, minimize cost overruns. Further, they can support interdisciplinary reviews due to their collaborative nature.

The results of this research are based on experts' opinions, and most of the experts come from academia. Thus, future research should test the effectiveness of using these lean techniques and their impact on minimizing cost overruns in the construction of transportation projects.

This research's findings support collaborative approaches in developing preconstruction processes to minimize construction cost overruns. These results might inspire owners and practitioners to boost collaboration within and across pre-construction processes in transportation projects.

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