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A THREE-LAYERED APPROACH FOR A LEAN SUBCONTRACTOR PROCUREMENT PROCESS

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ABSTRACT

It is generally recognized that subcontractors execute significant parts of construction works. This makes the subcontractor procurement process − from packaging to delivery method selection, budgeting, candidate selection, and so on − a cornerstone for the successful completion of construction projects. While the focus of the extant literature has been mainly steered towards the process of subcontractor selection and its related criteria, little emphasis has been placed on the procurement process itself and its implementation by general contractors. The main purpose of this paper is to develop a comprehensive lean methodology that may be applied by general contractors to improve subcontractors' procurement processes. To do so, a three-layered approach is proposed involving the realignment of steps within the process, the application of the choosing-by-advantages methodology, and the introduction of a digitalized subcontractor rating program. Then, the proposed approach is tested on a typical subcontracting procurement process adopted by a well-established construction contracting firm in the Middle East. Results show a significant reduction in the overall duration of the subcontractor procurement process. The offered methodology is viewed as a roadmap that can be generally adopted for reducing rework, eliminating waste, and enhancing the subcontractor selection methodology.

KEYWORDS

Lean construction, standardization, process, supply chain management.

INTRODUCTION

It is widely recognized that general contractors look to specialty contractors, or subcontractors, to perform specific tasks on construction projects. Hinze and Tracey (1994) mentioned that, particularly in building projects, it is common for 80-90% of the work to be performed by subcontractors. Subcontractors may provide specialized trade work such as painting, carry out specialized services such as electrical and mechanical, or provide labor services such as skilled craftsmen (Mbachu, 2008). Additionally, specific design works may be subcontracted to specialized firms. This reliance on subcontractors is rooted in several reasons. Bennett and Douglas (1990) argued that tasks in construction are specialized in such a way that no one firm can perform them all; therefore, many specialist contractors with specific expertise are required to meet the industry's complex demands. Additionally, Hsieh (1998) suggested that general contractors use subcontracting to allow the downsizing of their firms and to ensure better handling of unstable market conditions. Furthermore, operations of the average general

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contractor are not sufficiently extensive to afford full-time employment of skilled craftsmen in each of the several trade classifications needed in the field, nor is it feasible for these companies to own, operate, and maintain specialized equipment that may have only limited use during a project, as presented by Arditi and Chotibhongs (2005).

Typically, in building construction, there is a need for involving many specialized trades; this dictates the extent to which work packages are subcontracted and, therefore, leads to general contractors initiating frequently one or more subcontractor procurement process. Given the time-limitation characteristic of construction projects and the importance of making informed decisions within short time frames, the application of lean principles can be beneficial in ensuring their success from time, cost, and quality perspectives by facilitating the selection of the right subcontractor to execute the works. This study aims to develop a comprehensive lean methodology that may be applied by general contractors to improve subcontractors' procurement processes by reducing the overall process duration, limiting rework, and improving the quality of the decision-making approach.

LITERATURE REVIEW

One of the most significant factors affecting the costs of construction projects and the entire construction industry is the efficacy of subcontracting procurement processes (Yin et al., 2014). In the extant literature, the focus has been mainly steered towards the process of subcontractor selection and its related criteria, subcontractor rating methodologies, and the relationship between general contractors and subcontractors. For instance, according to a study by Arditi and Chotibhongs (2005), the process of bid shopping by general contractors is one of the problematic issues in subcontracting and may cause detrimental consequences on the overall performance of the project. Possible solutions are therefore presented based on the input of surveyed professionals, including owners requiring general contractors to provide bid listings and subcontractors refraining from providing contractors who shop bids with quotations. Other issues in subcontracting practices are also addressed in their study including payment timeliness, provision of construction insurance, site safety issues, and productivity issues (Arditi & Chotibhongs 2005). Ulubeyli et al. (2010) discussed the subcontractor selection practices of Turkish contractors in international construction projects. Their study reports that, although most contractors employ previously known subcontractors, no systematic processes nor models are put in place as a means for making an optimal selection. It is also highlighted that subcontractors are frequently selected based on the decision-makers' own experience rather than via a selection process and suitable evaluation technique (Ulubeyli et al., 2010). In another study that forms part of the ongoing discussion around partnering and subcontractor selection, Hartmann and Caerteling (2010) discusse price and trust as subcontractor procurement mechanisms and explore how the interaction between the two is important in the selection of subcontractors. Abbasianjahromi et al. (2013) proposed a model for subcontractor selection based on the fuzzy preference selection index. The value of their model lies in eliminating the weighting criteria phase in selecting the optimal subcontractor where weighting attributes is a challenging task. Polat et al. (2015) used the genetic algorithm technique as a methodology for selecting subcontractors for all work packages in a construction project considering time, cost and quality performances. El-Khalek et al. (2019) identified subcontractor prequalification evaluation criteria and their impact on project success. Among the evaluated criteria, on time delivery of materials, failure to complete contract due to financial problems, subcontractor's difficulty in reimbursement, reputation, and tender price were found as the most influencing ones.

On the other hand, the implementation of the choosing-by-advantages (CBA) as an alternative method of subcontractor selection has been heavily explored in the construction industry literature. Notable recent publications include Demirkesen and Bayhan (2019) in

which twelve factors for evaluating alternatives are presented and connected to a seven-step CBA procedure. The result is a selection which ranks highest importance of advantages and lower cost of advantages. El-Kholy (2022) presents a rigorous analysis of the proposed technique using CBA and explores an illustrative case study for testing. It is concluded that the proposed methodology takes into account aspects of decision-making that are not considered in traditional methods and paves the way for further exploration in the literature. Limited studies are found to tackle the analysis of traditional procurement procedures and the presentation of innovative processes. Yin et al. (2014) presents a procurement process that is mapped against the seven types of waste which forms the basis of lean theory. It discusses how traditional procurement methods for subcontracting tend to bound opportunities for price negotiation, constructive contractor relationships, and the avoidance of future problems such as waste, risk in construction, and engineering interface (Yin et al., 2014). In an attempt to address this, a Lean Subcontracting Procurement Process (LSPP) is presented which is initiated by a subcontracting plan based on a seven-arrangement operation plan that is aimed at eliminating various types of waste in construction projects, and which involves four types of operating flows. The implementation of this LSPP in its collaborative nature resulted in cost reduction and shortened construction time (Yin et al., 2014). Suresh and Arun Ram Nathan (2020) discuss lean procurement in construction projects using the total interpretive structural modeling (TISM) approach to classify readiness factors and build a model which helps construction companies in India to begin the implementation of lean production. They focused on material procurement which is very similar to that of subcontractor procurement in construction sites. The model analysis identifies the techniques of awarding purchase contracts, checking material specifications, negotiating with suppliers, and subtracting the cost of material as the model's driving forces. The change of these four factors has gained importance in Lean procurement execution as they directly affect other sections of the organization.

The focus of the construction industry literature has mainly been directed towards the process of subcontractor selection, the criteria used in the decision-making process, and the drawbacks of these traditional methodologies. Little emphasis has been placed, however, on the subcontractor procurement process itself and its implementation by general contractors. This study presents an in-depth analysis of the steps involved in the subcontractor procurement process in a typical building construction project and proposes a three-layered approach rooted in the application of lean principles to achieve a shorter and more efficient process.

METHODOLOGY

This study follows the Design Science (or constructive) research approach which entails the creation of a solution for a practical field problem (Rocha et al., 2012). Namely, this study aims to propose a comprehensive lean approach that may be adopted by general contractors to reduce the waste embedded in the subcontractor procurement process. The problem is identified through direct observations of the subcontractor procurement process followed by a well-established general contracting firm in the Middle East. The solution artefact is developed through a multi-stage process that includes data collection, data analysis, and the proposition and evaluation of a three-layered lean subcontractor procurement process. In the first stage, data with respect to the steps followed during the subcontractor procurement process in three recent tower construction projects was collected through surveying procurement records such as internal communications, exchanges with subcontractors, and meeting records, and through discussions with team members that were involved in the projects of interest. For the purpose of this research, the three selected projects have been awarded following the design-bid-build approach to project delivery. This is important because, under more collaborative project delivery methods, the structure and the timeline of the procurement process would be completely different. The three projects are of similar value (around $70 Million) but with

different scope of work. More importantly, these projects are relatively in the same location and were undertaken within the same timeframe; this is of particular importance in eliminating external factors such as the effects of economic instability on the decision-making process and consequently on the procurement strategy as a whole. The location of the projects is also of importance as it plays a major role in the availability of subcontractors to choose from. Accordingly, the current state of the typical procurement process followed by the general contracting firm is mapped along its corresponding data. Then, the analysis stage of the data collected allowed the identification of the waste embedded in the process and also unveiled opportunities for improvement. Finally, a three-layered process is developed and includes incorporating the CBA decision-making process and integrating lean concepts with digitalization techniques to form a comprehensive lean subcontractor procurement process.

DATA COLLECTION

The contractor's typical procurement procedure adopted on various projects, and particularly on the three building construction projects of interest to this study is explored by identifying and mapping the various involved stages of the complete process starting with a subcontracting plan and ending with a signed subcontract. The flowchart in Figure 1 reflects the current state map of the typical subcontractor procurement process and depicts its various stages along with the various departments involved, each according to its role within a stage. These include a total of 6 stages (sequenced horizontally, left to right) and involve several departments as well as external stakeholders (displayed vertically); particulars of these parties and their functions within the subcontractor procurement process are detailed in Table 1.

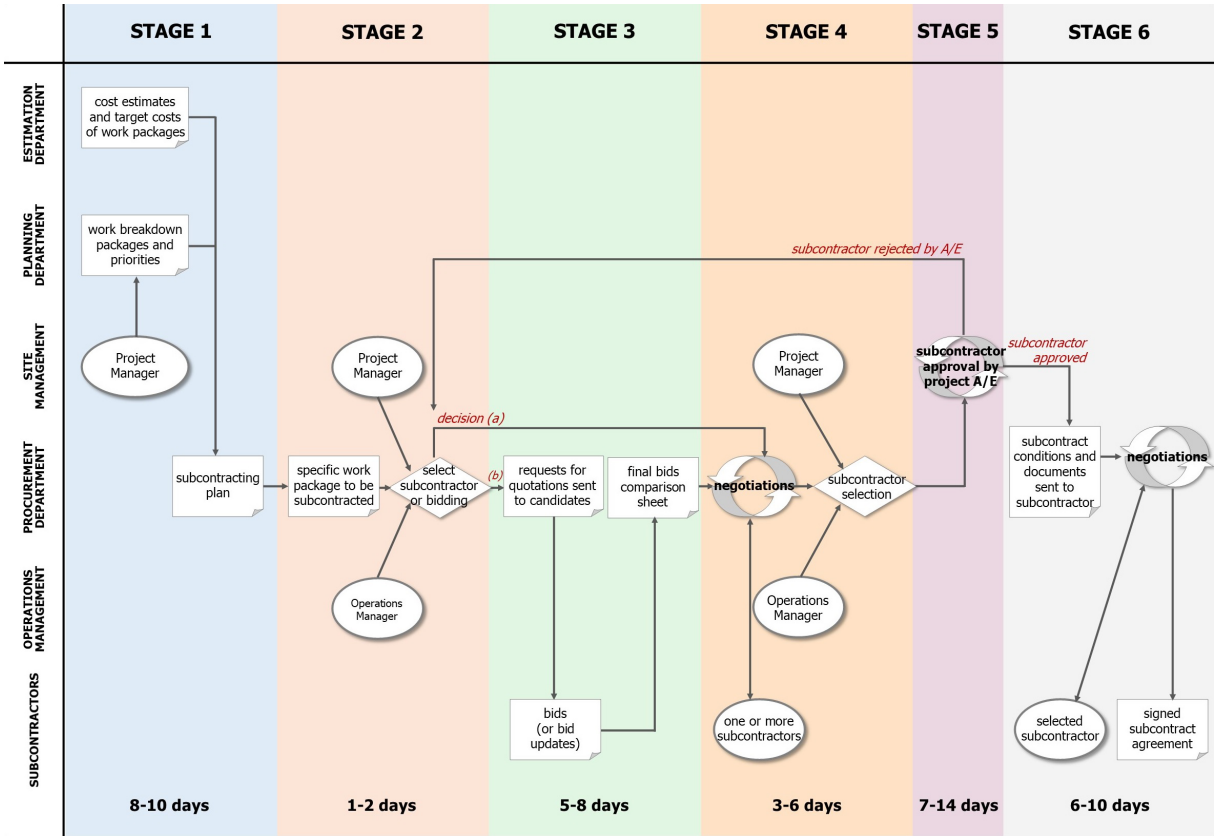

Figure 1: Flowchart of the Typical Subcontractor Procurement Process

The procedure is initiated in Stage 1 by a collaboration between the estimation and planning departments in direct coordination with the project manager and the procurement department,

which produces a subcontracting plan that will form the starting point of any and all process initiation. Stage 2 is then started with a specific work package that comprises a target cost and a target schedule. It's important to note that, in this case, stage 2 is instigated purely based on the subcontracting plan and does not take into account any project delays or schedule changes. The procurement department shortlists a number of subcontractors who are suitable candidates for completing the subject works from whom they may or may not have received prices during the tender stage and presents them to the project manager and operations manager in a strategic decision-making meeting. During this meeting, a decision must be made on whether negotiations shall be made with a single suitable subcontractor (i.e., decision "a") or else to proceed with bidding (i.e., decision "b"). The former decision is normally a result of the scope complexity and characteristics of the subject work package, combined with the availability of specialized subcontractors in the market. The factors affecting the decision and the implications of the decision-making methodology will be discussed in subsequent sections.

Table 1: Parties Involved in the Subcontractor Procurement Process

Party	Internal/ External	Stages Involved	Main Role in the Process
Estimation Department	Internal	Stage 1	Provide information about the pricing strategy used during tender and the target cost of each work package to preserve planned profits.
Planning Department	Internal	Stage 1	Provide required information regarding the deadline for procuring a subcontractor for each work package (priorities) as well as the completion date for each work package.
Site Management Team	Internal	Stages 1, 2, 4, 5	Project Manager provides their opinion and guidance on the whole process concerning their preferences for the packaging of the works as well as specific subcontractor preferences. Site team is also in charge of the process of getting the A/E's approval on subcontractors (this may include iterations).
Procurement Department	Internal	Stages 1, 2, 3, 4, 6	Starting with a subcontracting plan, the goal is to ultimately produce a subcontract agreement with the selected subcontractor.
Operations Management	Internal	Stages 2, 4	Offer strategic planning, guidance, and judgment regarding subcontractor selection in line with the firm's business plan.
Subcontractors	External	Stages 3, 4, 6	Compile and submit bid prices and, if selected, provide their company profile for approval and, once approved, sign a subcontract agreement with the contractor.
Project A/E	External	Stage 5	Consent to the appointment of subcontractors.

In the case of decision (a) being made, stage 4 is initiated which will be discussed shortly. In case of decision (b), stage 3 commences with requests for quotations sent to candidate subcontractors. These candidates may have previously submitted their bids during the tender stage or may be newly invited. Once all bids have been received from the candidates, a bid comparison sheet is prepared showing an item-by-item comparison of the priced Bills of Quantities (BOQ), noting that some subcontractors may choose not to submit a bid for many reasons such as poor previous experience with the contractor, project location not being suitable, project scope being too risky for their business, and many others. Before making a final decision, stage 4 begins with a round of negotiations with either the selected subcontractor(s) from stage 2 or those whose bids were the lowest in stage 3. This step is purely commercial, whereby the

price is negotiated in order to reach the target price; it may however be omitted if the presented bids already meet the target price presented at the beginning of the process by the estimation team. Once this step is completed or omitted a decision is made, and a subcontractor is selected with the guidance and judgement of the project manager and the operations manager.

Before proceeding with the subcontract preparation, and should the main contract conditions stipulate this, the subcontractor's details, profile, and previous experience are submitted to the project's Architect/Engineer (A/E) for their consent. Should the subcontractor be rejected, stage 2 is reinitiated in order to make a new selection. Otherwise, a subcontract is prepared and sent to the subcontractor for review and signature. Typically, a round or two of negotiations take place regarding the conditions of the subcontract, and, in rare cases, subcontractors may impose an addition to their price to bear the risks stipulated in the subcontract. Finally, once the contractor and subcontractor reach common grounds regarding the subcontract conditions, an agreement is signed, and the subcontractor proceeds with the works. The complete subcontractor procurement process, as presented in its current state and including all 6 stages, is found to take a minimum of 30 working days to be completed and a maximum of 50 working days, assuming that the first decision is (b) and that the subcontractor is approved by the project A/E from the first round.

DATA ANALYSIS

The collected data clearly show big room for improvement. Given the extent to which work packages are typically subcontracted on building construction projects, a total duration of 30 to 50 days per package could potentially cause major delays. Below are the various types of waste identified in the process:

- The inherent push system based on which the initiation of stage 2 is made: The subcontracting plan, which is the basis for initiating a procurement process, is prepared in the first weeks of the project life. As such, it does not take into account any schedule and priority changes or the progress of procurement itself, which may cause a figurative inventory of packages that are not required to start just yet. Scope modifications, schedule delays, or other adjustments may require certain work packages to be procured in a sequence that is different from that of the subcontracting plan.
- Major rework is embedded in the process, particularly with the subcontractor selection process. Holding two decision-making meetings with various parties, as well as having to restart the process of selection in case the project A/E does not give their consent are two major forms of waste. Additionally, leaving subcontract negotiations until the last stage also causes unnecessary rework; this could easily be avoided by providing the subcontractor with a draft agreement earlier on in the process to make them aware of its conditions.
- The decision-making process is plagued with human error. With no specific decision matrix, it is purely based on the opinions of the procurement department, the project manager, and the operations manager. For instance, previous experience with subcontractors, a major contributor to the selection process, is not referred to or well-documented in order to be used as a benchmark.

PROPOSED THREE-LAYERED APPROACH

To address the identified flaws in this subcontractor procurement process, a three-layered approach aimed at reducing rework, eliminating waste, and enhancing the subcontractor selection methodology is proposed and is illustrated in Figure 2. The first layer involves a change in the way a new process is instigated as well as a simple realignment of processes at two levels of the procedure, namely the process of securing the project A/E's consent on the

subcontractor and the process of negotiations of the subcontract conditions between the contractor and the subcontractor. With regards to the process initiation, and in order to address the issue of frequent changes in construction projects, a pull system by which work packages are only sent to the procurement department for action at the last responsible moment is proposed; this allows them to sign the subcontract before the works are due to be commenced (plus enough lead time to allow subcontractors to procure the materials needed). In addition to ensuring the right work packages are procured at the right time and with the most up-to-date project information, the adoption of this lean principle allows the workload to be pulled in such a way that ensures no package is procured too soon, and hence the possibility for abortive works is reduced.

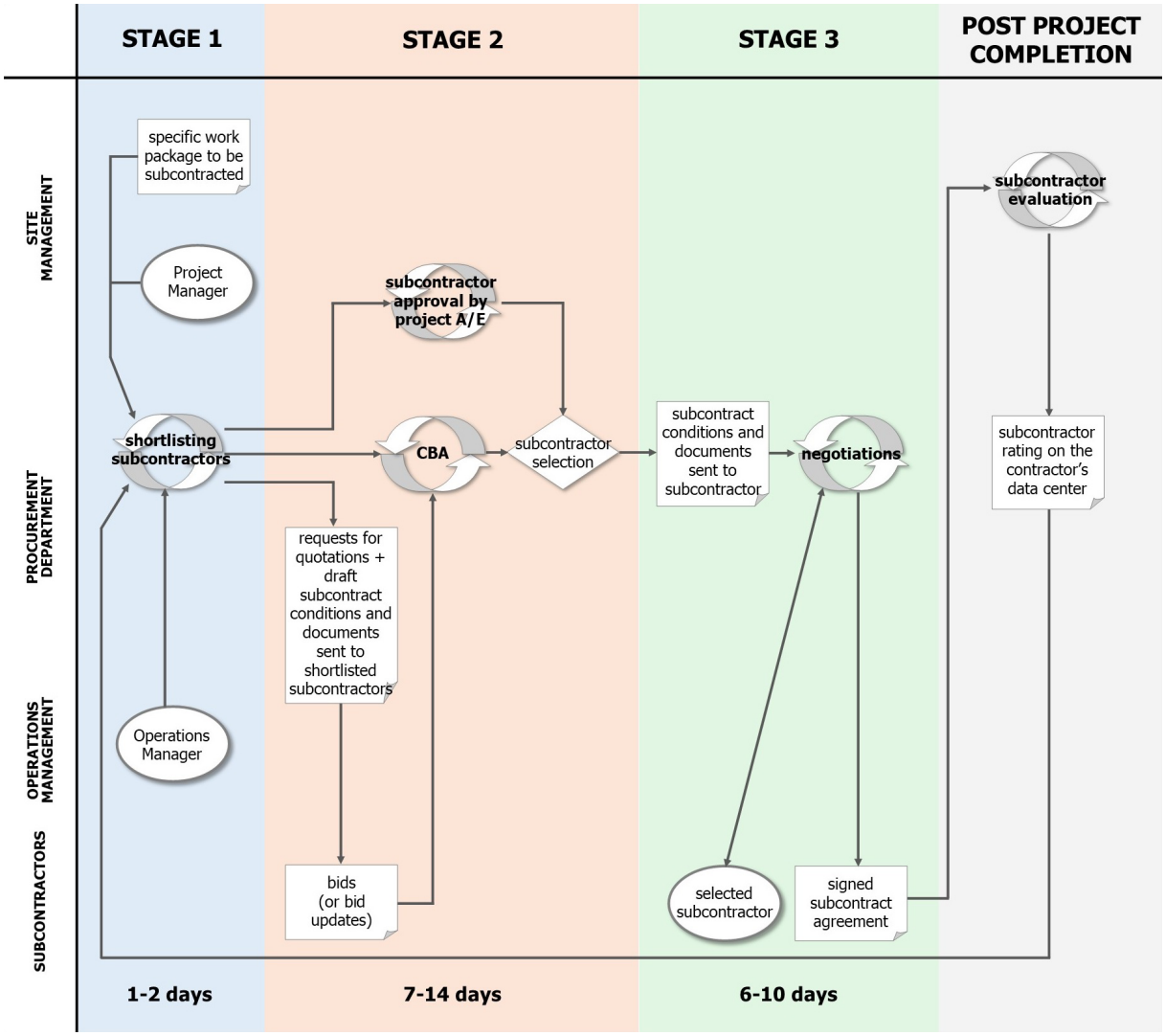

Figure 2: Proposed Three-Layered Subcontractor Procurement Process

In order to avoid possible rejection by the A/E after having invested time in selecting and negotiating with a selected subcontractor, it is proposed to submit for approval the details of shortlisted subcontractors from the optimized stage 2. By doing this, time is saved by initiating this process in parallel with the decision-making process of selecting a subcontractor in addition to avoiding rework in case consent is withheld by the A/E. At another level, it is also suggested to provide the shortlisted subcontractors with a draft of the subcontract conditions and documents along with the request for quotation in stage 3. This allows subcontractors to be

aware of these conditions and account for any risks in their prices, hence avoiding disruptions in the process or possible price changes prior to signing the subcontract.

The second layer addresses the subcontractor selection phase of the procurement procedure. As discussed, the current state not only necessitates iteration by having two decision-making processes running at two different stages, but it also leaves much room for human error as it is purely based on opinion and advice, albeit being from professionals and stakeholders in the project. The choosing-by-advantages (CBA) is proposed as a method for enhancing the decision-making process by using multiple qualitative and quantitative criteria. The CBA framework proposed by El Kholy (2022) is proposed to be adopted as a means for enhancing the decision-making phase of the subcontractor procurement process. The main advantages of the CBA method are (a) its ability to accommodate the comparison of multiple alternatives (subcontractors in this case) over several factors, (b) its ease of use by creating a straightforward matrix structure using simple software which may be used with any work package on any project, and (c) reducing the possibility of human error of judgment through its scientific basis of calculation, which in turn reduces cycle time and minimizes the amount of coordination required between departments.

The third and final layer is related to the shortlisting of subcontractors and the use of historic data in such a manner that allows for continuous improvement and learning. An online-based subcontractor rating program within the contractor's Enterprise Resource Planning system is suggested in which data about subcontractors' expertise, contact details, as well as performance history is compiled. This stage requires project managers to rate subcontractors at the end of every project against a set of pre-determined criteria from technical, commercial, and time perspectives. The subcontractor rating stage takes place beyond the procurement process, long after the subcontract agreement is signed. It forms an integral part of the procedure enhancement by creating a feedback loop essentially based on the principle of continuous improvement. Namely, it paves the way for sustained benefits as a result of recurrently examining the performance of subcontractors and, in turn, the efficiency of the subcontractor procurement process itself. By having all this information readily available to the procurement department, a shortlist of potential candidates for the performance of any work package is easily created, which will form the basis for starting the CBA decision-making process as well as sending out requests for bids. This list of subcontractors may also be submitted to the project's A/E for approval in order to save time and reduce reiteration. It should be noted that this may not be accepted by all A/Es. However, by adopting the previously suggested rating system, one of the criteria could be the previous consent by A/Es to the specific subcontractor. As such, the shortlist will take this data into account by eliminating those that have previously been rejected by the specific A/E on the project.

DISCUSSION

The application of the proposed three-layered approach resulted in reducing the overall duration of the subcontractor procurement process from 30-50 days to just 14-26 days and in reducing the need for the involvement of many different parties. The subcontracting plan is now considered to have been completed prior to the initiation of stage 1 and the trigger for the procurement process becomes a specific work package requested by the site team in coordination with the planning department. The underlying reason is, as previously discussed, the application of a pull system that is based upon real-time project requirements, therefore allowing for better time management and reducing the need for rework.

The governing factor in determining the duration of stage 2 is the period stipulated under the main contract for the A/E's reply to submittal, assumed to be anywhere between 7 and 14 days typically. This is the longest of the durations among the three activities taking place simultaneously during this stage, namely (a) the request and receipt of bids from shortlisted

subcontractors, (b) the setting up of the CBA framework, factors and determining criteria with their weights, and (c) the consent of the A/E. In this case, since a list of subcontractors is submitted (or in the case discussed earlier of the A/E rejecting this setup, the historical data will lead to the submittal of a subcontractor likely to be consented to by the A/E), the risk of rejection is very low, and rework is highly unlikely. As such, the longest among the durations of Stages 3, 4, and 5 of the conventional procurement process was adopted as the governing duration for Stage 2.

The final stage of subcontract conditions negotiations is considerably shorter than in the current state map since the subcontractor has already been made aware of them when requesting new bids in stage 2. By doing so, the subcontractor would have the opportunity to make allowances for the mitigation of any risks they deem necessary. While there will still be conditions and details to be negotiated at the final stage prior to subcontract signature, the extent of these will be limited to those of which the subcontractor deems completely unacceptable to them.

Finally, the proposed approach, having been developed based on a main contractor's adopted procedure in building construction projects, is particularly applicable to such projects. However, this methodology is indeed applicable to any project that is awarded following the design-bid-build approach to project delivery and that entails a need to go through a subcontractor procurement process. What makes it appealing in building types of construction is the high volume of work that is typically subcontracted, and which is commonly more extensive in building construction than other types of construction projects and where the number of work packages sub-let to specialty subcontractors is more sizeable, leading to many more instances of running the process.

CONCLUSION

Depending on the level of complexity and time limitation of the construction project at hand, contractors may decide to execute the various work packages of the project either in-house or with the help of subcontractors.The subcontractor procurement process is a complicated procedure involving input from different parties and encompassing several stages where decision-making takes place. Given the extent to which work packages are subcontracted on building construction projects, the selection of the right subcontractor and having a signed subcontract at the right time is of paramount importance. While the extant literature has thoroughly examined the issue of subcontractor selection, little emphasis has been placed on the procedure adopted by contractors to turn a work package into a subcontract agreement. This study aimed at closing this gap in the literature by examining a typical subcontractor procurement process of six stages, with potential judgement-related risks, and proposing a three-fold enhancement rooted in the application of lean principles to achieve a shorter, more efficient process. Namely, the proposed approach involves realignment of the steps within the subcontractor procurement process, coupled with the application of choosing-by-advantages methodology and a digitalized subcontractor rating program as a means for achieving a process with limited non-value-adding activities. The offered methodology is viewed as a roadmap that can be generally adopted by general contracting firms to reduce rework, eliminate waste, and enhance the subcontractor selection process.

The limitation of the study is that the process mapped reflects the typical process followed amongst general contractors of similar size undergoing building construction projects in the same region. It is recommended for future studies to have the same process studied with multiple contractors and on other types of projects such as infrastructure projects. Furthermore, while this study paves the way for examining the effectiveness of existing procurement processes adopted by contractors and how the application of lean principles can be of benefit, further research would be helpful in bridging the gap between available subcontractor rating

criteria and digitalization by developing industry tools that allow the implementation of those criteria into an innovative subcontractor rating mechanism.

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