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A Case for Incorporating Pre-construction Cost Estimating in Construction Engineering and Management Programs

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A Case for Incorporating Preconstruction Cost Estimating in Construction Engineering and Management Programs

The need to effectively manage costs during the construction phase of a project to meet budget constraints is widely understood by both practitioners and academics. Most, if not all, Construction Engineering and Management undergraduate and graduate programs require that students complete construction cost estimating courses as part of their core curriculum. However, the value of estimating the owner's planning, design, and procurement costs during the preconstruction period is not typically included in the Construction Engineering and Management curriculum. Preconstruction costs are usually defined as all work required to develop and advertise construction documents to a point where the construction contract can be awarded. Final project construction documents literally define the level of required construction quality and as such, must also be of adequate quality to achieve the construction project's ultimate success. Thus, failing to provide an adequate and sufficient preconstruction budget constrains the necessary resources to fully develop these documents and may unintentionally constrain the document development process causing planners and designers to match their level of effort to the amount of time permitted by the budget. Not only may the quality of the construction documents be negatively impacted but design factors of safety may be unnecessarily increased due to a lack of time to do detailed design analyses. It can also, eventually, have an impact in design issues related to serviceability, operation, or maintenance. Lastly, the increased use of alternative project delivery methods, such as Design-Build and Construction Manager-at-Risk, have created a need to teach preconstruction cost estimating in academic programs to ensure that graduates have the necessary knowledge and skills to effectively manage construction projects delivered using both traditional and alternative methods. This paper contributes to the body of knowledge by demonstrating the importance of accurately estimating owner's preconstruction costs and proposing a framework to assist engineering educators to integrate the subject into the required curriculum in Construction Engineering and Management programs.

Introduction

From an owner's perspective, Preconstruction services (PCS) consist of all the work completed on the project from the conception through the contract award. It includes activities such as conceptual design, feasibility studies, preliminary engineering, and many other activities until the construction contract is awarded. Capstone courses are offered at most Construction Engineering and Management programs in order to integrate and apply the knowledge gained during a student's academic degree. According to Gehrig et al., capstone courses "are usually structured in a manner that requires student teams to design construction operational plans for realistic projects" [1]. Often, the goal is for teams to mirror standard industry practices during the development of bid-level cost estimates, project schedules, etc. and allows students the opportunity to demonstrate and integrate the myriad of skills and knowledge learned over the course of the undergraduate curriculum" [1]. In capstone courses, students typically develop construction documents for critical review by faculty and invited reviewers such as industry professionals [2]. Students are often asked to evaluate if their project is economically feasible. In

order to evaluate economic feasibility, students need to include costs for both the pre-construction and construction phases. Since cost estimating for the construction phase is taught in most, if not all, construction engineering and management programs, students are able to determine these costs using the knowledge they gained in prior courses that they have completed. However, when asked to estimate owner's pre-construction costs, students often struggle because this topic was not adequately covered in their prior courses. The pre-construction costs that students are asked to determine include but are not limited to the following: permitting costs, cost of surveying utility locations, environmental, geotechnical and other analysis as appropriate, preparing contract documents (conceptual, preliminary and final construction documents), advertising for bid, holding a pre-bid conference, receiving and analyzing bids, etc. [3]

In the National Cooperative Highway Research Program (NCHRP) Project 15-51: Preconstruction Services Cost Estimating Guidebook, PCS are classified in four development phases [4], which are the following: Planning, Programming and Preliminary Design, Final Design, and Advertise and Bid, see Figure 1. The Planning phase consists in the determination of the project's purpose and need, also the type of project, new or improvements. It is the phase to consider environmental factors, facilitate public involvement and interagency conditions. The following phase is Programming and Preliminary Design in which the project's scope of work details are defined. In this phase the environmental factors considered in the planning phase are further analyzed to obtain the environmental clearance. Furthermore, design criteria and parameters are determined leading to schematic developments, economic feasibility analyses, public hearings, preliminary plans and funding authorization. The next phase is Final Design. This phase consist in the development of plans, specifications and a more detailed cost estimates because of the design completion. Finally, the last phase before construction is Advertise and Bid. Contract documents, bid advertisements, pre-bid meetings are held in order to select the contractor who will initiate the contract with the owner. After the mentioned steps, the owner receive and analyze bids, determine the lowest bidder and initiate contract. Almost all of the activities related to each of the phases involve a certain level of expertise personnel who work several hours in order to design and develop a project for it to be constructed. Even though the quality and success of those activities that will result in a successful and efficient construction project is influenced by the quality of the PCS, the costs related to PCS are often overlooked. Figure 1 presents a PCS timeline and some of the activities related to each of the development phases.

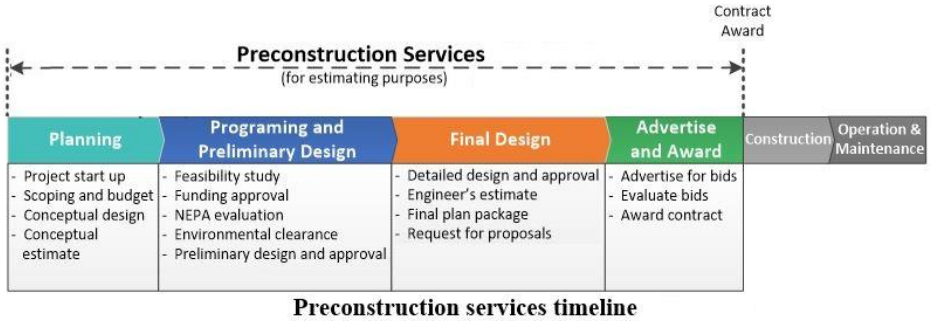

Figure 1: Preconstruction Services Timeline (Modified) [5]

The increase funding uncertainty and tightening of budgets in construction projects has resulted in scrutiny of every dollar spent in the construction phase of building and highway projects. While detailed estimates are routinely developed to estimate material, labor and equipment costs during the construction phase, estimates of costs during the preconstruction phase are rarely performed. Gransberg et al, conducted a research study that analyzed the relationship between the amount paid in the design phase to develop plans and specifications with the difference in costs between the engineer's initial estimate of the project and the actual construction final costs [6]. The difference between these amounts is called "cost growth from the initial estimate" (CGIE). Traditionally, the metric used to determine cost growth in construction projects only takes into consideration the original construction contract award and the final contract costs. The CGIE is an approach to measure if the amount of time and resources invested at the early stage of planning and design does make a difference in terms of decreasing the amounts of discrepancies, errors and omissions, which eventually will trigger construction costs to vary from the original cost in the construction contract award. Therefore, the purpose of the research study was to relate the "quality" of the design with the costs variations from the estimated project costs to the actual and final construction costs. CGIE results can be either positive or negative. If CGIE is positive, it is an indication that the final construction costs surpassed the initial engineer's estimate. Contrarily, a negative CGIE indicates that final construction costs were less than the original estimate. In this case, a negative CGIE is the evidence of inefficient use of available capital in public works [7]. A construction project with a negative CGIE indicates that money that could have been used in additional projects has been unintentionally withheld as a contingency against risks that were not realized. In other words, the project's cost was over-estimated. The CGIE metric depicts an ongoing problem in the construction industry between the quality of the planning, design and construction documents, and the eventual cost growth due to poor investment in these early and important stages.

This research study [6] calculated the design fees as a percentage of construction cost and the CGIE as a percentage of the contract cost based on data from 31 projects worth $90 million from the Oklahoma Turnpike Authority (OTA). The projects were divided in two types, roads and bridges. The construction work in the majority of the road projects was related to roadway construction, pavement, reconstruction, upgrade or rehabilitation. In terms of the bridge projects, the majority of the works were related to construction, reconstruction, rehabilitation or upgrade. A total amount of 13 road projects worth $63.6 million and 18 bridge projects worth $26.4 million. The average design fee for those projects was 5.21% and the average CGIE was 9.65%[6]. When projects were divided into road projects and bridge projects, the results presented another reality. In road projects the average design fee was 1.96% and the average CGIE was 36.31%. For bridge projects, the average design fee was 7.61% and the average CGIE was -9.60%. In order to demonstrate the importance of properly estimating preconstruction costs it is important to analyze and understand the correlation of the results from these projects. Based on the research study, the relation between the design fee and the cost growth is inversely proportional. In that case, a decrease in design fees leads to construction cost growth. The average design fee for road projects is lower than the average for the total amount of projects, but the CGIE is approximately four times higher. This results can lead to the conclusion that the effect of underfunded designs can be higher construction costs. In terms of the bridge projects, the

average design fee is higher than the total average and the CGIE is negative. In this case, higher design fees lead to a negative construction cost growth. In a sense, a negative CGIE means that the adequate design was provided, but it also means that it was an inefficient use of funds, as mentioned before. Therefore, these results confirm the relation between design and preconstruction costs and the consequences it has in terms of cost growth for the construction phase.

In times where faster is the norm, the quality in the development of construction documents have been compromised. A survey by the Construction Management Association of America demonstrated that the "demand for increasing speed of project delivery is the top reason for decline in construction document quality" [8]. Engineers have to fulfill owner's needs and requirements with less time and less resources resulting in plans and specifications with significant amount of missing information. The absence of important information in the construction documents leads to construction contract modifications, which increase construction costs. According to studies by Morgen (1986) and Kirby et al. (1988) 56% of all modifications are directly related to design deficiencies [9, 10]. Therefore the studies found that the quality of a constructed project is greatly influenced by the quality of the documents developed in the preconstruction phase. Poor design quality leads to the need to correct design errors and omissions during the construction phase and has long been recognized as a cause of construction cost and time growth [9, 10, 11, 12]. Burtati et al. found that on average poor design quality was responsible for adding 9.5% to the final contract amount [13]. Figure 2 presents the relationship between the investment in design fees and the construction phase cost growth. It is evident that to a point investing in the preconstruction design reduces the percentage of post-award construction cost growth.

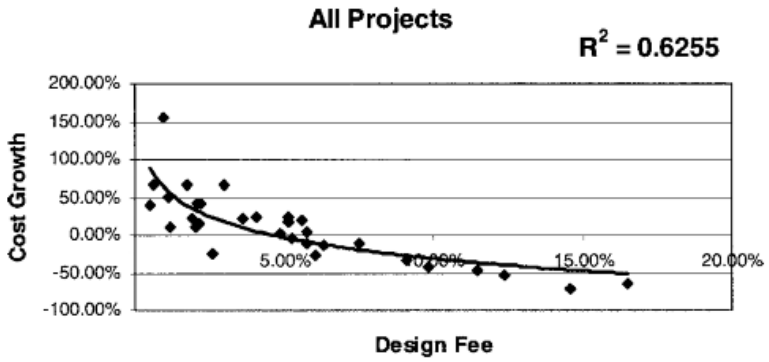

Figure 2: Cost Growth relationship with Design Fees Investment [6]

In order to develop design solutions and produce drawings and specifications, design professionals (such as architects and engineers) typically charge by the hour. Traditionally, the total design services fee is calculated either as a percentage of anticipated construction costs or by square footage. Few owners appear to place importance of appropriately funding the preconstruction phase and thus by estimating the design services fee using a percentage of construction costs or by square footage, they inadvertently cap the design effort [4]. To estimate the number of hours that design professionals can spend on a given project, architects and

engineers divide the total preconstruction budget by their hourly rate. If the amount of hours is not enough to complete the design, design professionals must figure out how to complete the design while fulfilling their contractual and ethical obligation to the owner. Without sufficient hours to complete a design due to a tight hourly budget, design professionals often over-design the project's components [14]. For example, structural engineers can spend an adequate number of hours designing a foundation to ensure that the footprint of the foundation is as small as possible while meeting its functional requirement. If the structural engineers do not have enough hours to do a detailed design, they can increase the factor of safety, and thus increase the foundation footprint, and still produce a design that is viable. Spending less time in developing the design solution decreases the design costs but greatly increases the construction costs because the foundation footprint is larger, thus needing more labor and material to be completed. Since the design costs are significantly less than the construction costs in any given project, saving money in the design phase may be counterproductive to the overall goal of decreasing project costs. The objective of this paper is to demonstrate the importance of accurately estimating preconstruction costs and proposing a framework to assist engineering educators to integrate the subject into the required curriculum in Construction Engineering and Management programs.

Construction Cost Certainty

The constructed project's ultimate quality is defined during the preconstruction planning and design process [15]. Therefore, to prevent the escalating construction cost growth due to corrections for errors and omissions in the construction documents, preconstruction services should be properly funded. Accurate preconstruction services budgets should be established in order to appropriately develop and quantify the project's scope, considering the technical scope and also the site-specific factors that have an impact in the technical design solution. Traditionally the PCS budget is calculated by, first estimating the project's construction cost and then multiplying it by a percentage that is based either on policy or on an average of historic PCS costs. The problem with this method is that the percentage used to calculate the budget is not specific to the project's scope and furthermore that construction costs change as project development progresses. This can lead to underfunded preconstruction services which ultimately compromise the design, leaving the owner with poor construction documents due to inadequate funding.

Another typical approach at PCS is to deliver projects as inexpensive as possible, focusing on cost savings. According to the Crosset study, 82% of projects over $5.0 million overrun their budgets [16]. In addition to this study, as mentioned before, design deficiencies generate the majority of post-award contract modifications. This means that focusing on project cost savings have been counterproductive. The idea should change from "minimize costs" to "maximize cost certainty". Construction cost certainty is the result of adequately funded PC during planning, design and procurement process. PCS costs should be viewed as an investment, not an opportunity to diminish costs which eventually will result in poor design quality. Cost certainty can be enhanced with the production of high quality construction and bidding documents. The owner's objective should be increasing cost certainty with the proper investment in the preconstruction phase which will result in benefits such as better costs management through the

project lifecycle and the reduction of risks due to high quality construction documents. This concept should be instructed as part of the solution for the construction cost growth problem mentioned before. Construction Engineering and Management programs should focus in developing the essential skills to identify, analyze, and accurately estimate preconstruction services leading to cost certainty which will result in effective project management practices and successful construction projects.

Methodology

The purpose of this study is to make a case for incorporating Pre-Construction Cost Estimating into the undergraduate and graduate Construction Engineering and Management curriculum. This study has the following two main research objectives:

1) Investigate the current state of teaching Pre-Construction Cost Estimating in Construction Engineering and Management and Construction Management programs.
2) Translate the results of industry based research to academia to adequately prepare our students to estimate costs from the pre-construction phase of a project to the end of its lifecycle.

In order to investigate the current state of teaching Pre-Construction Cost Estimating in Construction Engineering and Management programs and Construction Management programs a multi-prong approach was used. The multi-prong approach consisted of an extensive literature review that included searching for journal articles and conference proceedings that discuss teaching PCS. It also included searching through Construction Engineering and Management and Construction Management program webpages to investigate the course offerings and reviewing course syllabi. The approach also included informal conversations with faculty who attended the 2015 American Society for Engineering Education in Seattle, WA to investigate whether or not faculty include PCS cost estimating in their graduate and undergraduate cost engineering and management curriculum. Finally, case studies from construction projects were included to highlight the complexity and need for estimating Pre-Construction costs in our industry. The purpose of including case studies from the industry in this paper is to translate the results of industry based research to academia to adequately prepare our students to estimate costs from the pre-construction phase of a project to the end of its lifecycle.

Case Study Methodology

In order to determine PCS estimating is currently performed by Construction Engineering and Management professionals, a multi-prong approach was used. The multi-prong approach consisted of an extensive literature review, interviews with cost engineering professionals and case studies [16]. The results of the literature indicate that calculating a percentage of the total

costs is by far the most published and used method to estimate PCS costs. Information about other methods to estimate PCS was scarce.

The next step was to develop a structured interview. According to the US Government Accounting Office, structured interviews can be used where "information must be obtained from program participants or members of a comparison group… or when essentially the same information must be obtained from numerous people for a multiple case-study evaluation" [17] Potential interviewees were contacted and ask for their consent to be interviewed. If potential interviewees agreed to the interview the structured interview questionnaire was provided to them and a date was selected for the interview. Providing the interview questionnaire prior to the meeting allowed interviewees to review it and ensured that interviewees had time to understand what they were asked and ask for clarification if needed. During the interview, interviewees were allowed to digress which allowed for information was not initially contemplated in the structured interview questionnaire to be gathered,

The last step in the multi-prong approach was to collect case studies using the three principles developed by Yin for research data collection:

1.Use of multiple sources,
2. Creation of a database, and
3. Maintaining a chain of evidence [18].

Interview findings

From the information gathered during the interviews with staff, the Office of Bridges and Structures at Iowa DOT determine the current state-of-practice in the development of preconstruction cost estimates. The preliminary design completion is the stepping stone to estimate the work effort hours to complete the final design. This is due to the fact that project type, size and location have been already determined at this stage. Instead of focusing the estimates on costs, in-house estimates focus on hours in order to balance the work load of design staff determined by the engineering manager. The estimates of work hours rely greatly on the experience of a senior engineer which leads to arbitrary budgets. To account for an underestimate of hours due to project complexity the budgeted hours are adjusted at future target meetings. Even though the adjusted estimates are supposed to account for unexpected costs and allocation of resources, an insufficient budget is not identified until a substantial portion of the project is already completed, which makes the adjustments irrelevant.

In terms of outsourced designs, the engineering manager can influence the work effort budget only during negotiations. In this case, the consultant coordinator compares the estimates from completed projects designs to estimate the project budget. Over-head and fixed fee costs are useful in the determination of hourly costs of doing business for comparable projects. If there are no comparable projects, then the consultant use a factors approach. This approach requires an extensive professional experience due to the fact that the consultant estimator is assigning factors based on the perceived complexity of the project. In-house and outsourced methodologies are completely arbitrary.

Case Studies

In order to validate the importance of estimating preconstruction costs, two case studies were selected [4]. The Office of Bridges and Structures at Iowa DOT provided information on two final bridge design projects that have been constructed. Although the information provided is only about design, which is only one phase of the preconstruction services, it is sufficient to demonstrate how one major preconstruction function is estimated. Project 1 was completed by an external consultant designer and Project 2 by in-house designers. These approaches are useful to evaluate the effectiveness of the proposed estimation methods under both scenarios.

The construction costs for both projects were $2.0M – $2.4M and the design for both was a pretensioned prestressed concrete beam (PPCB) bridge. The preconstruction estimating methods for the case studies were compared based on the work effort hours only and were not converted into a final cost. Each case study involved two stages:

- Stage 1: collection of project scope information, the original preconstruction estimating hours at the allocation of the project and the actual final preconstruction hours
- Stage 2: a return by the research team to Iowa DOT with a WBS to collect perceived work effort hours based on each individual work tasks.

In stage 1, project scope information was gathered such as Type, Size and Location, preliminary bridge design and a copy of the final detailed bridge drawings to assess what design services were provided for each project. It also consisted in interviews with the design staff that helped the research team to quickly grasp the main aspects of the preconstruction activities involved.

In stage 2, the research team developed a WBS that could be used by both of the bridge design projects to prove that standardization could be achieved even though different design approaches were employed. One staff member completed work effort hour estimates for each project. Table 1 demonstrates the work effort hours estimated and the actual hours for both projects.

Table 1: Work Hours Estimates vs Actuals [4]

	Original DOT Estimate of Hours	*Actual Hours*
Project 1	*881*	*1068*
Project 2	*800*	*2188*

As shown in the case studies presented, the original DOT estimated number of workhours needed to complete the pre-construction phase was significantly less than the number of hours that the consultant was able to negotiate. However, the consultant still underestimated the number of hours that it would take to complete the project by 23%. Project 2 was an in-house project where the original DOT estimated number of workhours needed to complete the pre-construction phase was significantly less than the actual number of hours needed to complete the

pre-construction phase (800 hours vs 2188 hours) which represent a 65% difference [4]. It is important to put those percentages in terms of money. In both projects, if the preconstruction services were budgeted using the estimated hours by the experienced design estimators they would have been underestimated, which leads to deficiencies and poor quality construction documents. Therefore based on the results of the case studies, it is essential that design estimators and future construction engineering and management professionals have a better understanding of how to accurately estimate pre-construction services. Based on the need to accurately estimate PCS, this paper proposes the incorporation of PCS concepts and cost estimate methodologies to undergraduate and graduate Construction Engineering Management Programs. The following section presents and describes some of the topics related to PCS that can be included in a Construction Engineering Management curriculum.

Proposed PCS Curriculum

One of the authors of this paper attended the 2015 American Society for Engineering Education in Seattle, WA and asked in an informal conversation whether or not faculty include PCS cost estimating in their graduate and undergraduate cost engineering and management curriculum. The authors also reviewed the syllabi for cost estimating courses that is available online at program websites and syllabi that was shared by faculty that the author personally knows. Based on the results of the conversations and the review of course syllabi, the authors believe that value of estimating the owner's planning, design, and procurement costs during the preconstruction period is not typically included in the Construction Engineering and Management curriculum. This section outlines a proposed curriculum that can be included in current cost estimating courses or as a stand-alone course to assist engineering educators to integrate the subject into the curriculum in Construction Engineering and Management programs. Table 2, includes the proposed topics and is followed by a description of each topic.

Table 2: Proposed Preconstruction Topics for Construction Engineering and Management Curriculum

Topics
Preconstruction Services (PCS) • Definition • Phases • Costs
Top-Down PCS Estimating • Percentage Construction Costs • Dollar Values • Work Effort Hours
Bottom-Up Estimating
Functional Level Estimating • Process • Work tasks and Work Breakdown Structure • Level of Expertise Required • Hours to work tasks • Uncertainties

Top-Down PCS Cost Estimating

To estimate preconstruction services costs for projects at early stages the most appropriate estimating method is Top-Down Estimating. This method consists in the determination of preconstruction services costs based usually in the experience of the estimator. For projects with very limited information available in terms of requirements and scope, estimators analyze and compare the available historical data of preconstruction services for similar projects to calculate and develop the PCS estimate. The process is highly dependent on the estimator's knowledge, experience and professional judgement.

According to the NCHRP 15-51 Guidebook [4], there are other cost estimating approaches to calculate PCS costs. Most (highway transportation) agencies typically use one of the following three methods:

- Percentage of Construction Costs
- Dollar Values
- PCS Work Effort Hours

Percentage of Construction Costs

In this method, PCS costs are calculated as a percentage based on the estimated total construction costs for the project. The calculated percentages are generally ranging from 8% to 15%, according to the NCHRP 15-51 Guidebook [4]. The assumption behind this method is that PCS costs are consistently related to construction costs, which might be true for similar projects. As projects become more complex with varying characteristics the percentages can change significantly and assumed consistent relationship between PCS costs and construction costs is not clear. Project type, work type, grade change and environmental requirements, are some examples of factors that can influence the complexity of the project, therefore altering the calculation of the PCS costs in terms of a percentage of construction costs. This method is suitable to obtain a rough order of magnitude estimate of PCS cost.

Dollar Values

This approach calculate PCS costs based on total dollar value directly. Instead of assuming a percentage from the total construction costs, the estimator uses historical dollar values of PCS activities, taking into consideration factors affecting the costs (i.e. project type), to generate the estimate for the new project including direct and indirect costs related to those activities.

PCS Work Effort Hours

This method calculate the PCS work effort hours to estimate PCS costs. The approach intends to add together the work effort hours in activities or group of activities to get the total hours in order to calculate the PCS costs estimate. The process may not cover non-activity specific expenses, costs of mileage or permit fees, providing an incomplete PCS costs estimate. However it is useful to manage the available resources.

Bottom-Up Estimating

The Bottom-Up Estimating method requires a greater level of detailed information of the construction project. It is the result from the aggregation of functional level estimates derived from a work breakdown structure (WBS). Each functional level contains the estimate of the PCS costs for specific areas (i.e. structures, geotechnical and architecture) which are eventually combined to determine the total PCS costs for the project. The structure of the method facilitates decision-making at different functional levels regarding budgeting, scheduling and the allocation of resources.

Top-Down Estimating and Bottom-Up Estimating methods are related. Both are different approaches to determine preconstruction services costs. Furthermore, PCS costs can be estimated at every phase from Planning, Programming and Preliminary Design to Final Design. The method selection will depend on the available information at every stage. The estimates are required to make strategic financial decisions at the planning and programming stages, therefore the appropriate use of these models at the right timing will result in accurate estimates and well informed decisions.

Functional Level PCS Cost Estimating

This method structures categories called functional levels as individual tasks with particular resources assigned to each one. Instead of the Top-Down overall approach estimate, Functional Level Estimating works by passing the responsibility to each department/division to scope and price the work they need to complete. The estimates from each of the functional levels are eventually combined to form a project bottom-up estimate. Typical functional areas include, but are not limited to, the following:

- Geotechnical
- Surveying
- Structures
- Hydrology
- Environmental

Process for Functional Level PCS Cost Estimating

The Preconstruction phase consists in the delivery of many services and products. Each of these services and products require a level of effort in order to complete the tasks related to them which are often influenced by project type and location, regulations, resources impacted, and more. To quantify these kind of services it is essential to develop a scope of work that is sufficiently detailed to develop the cost estimates based on the specific tasks to be performed. Table 3 demonstrates the key tasks in sequential order to perform a functional level estimate.

Table 3: Process for Functional Level PCS Cost Estimating

Task #	Task Description
1. Develop Scope of Work	The scope of work is the starting point to develop a Work Breakdown Structure based on the activities that are required to complete the project.

2. Identify Work Tasks	Activity completion is achieved when all tasks related to it are completed. It is essential to identify each of the work tasks related in order to complete the activity successfully.
3. Assign Level of Expertise required for each task	The identification of work tasks will help with the proper selection of the level of expertise required to complete them. Each of the tasks should be assigned to the adequate personnel for its completion.
4. Assign Hours to Work Tasks	Preconstruction time has constrains. Therefore work tasks should be assigned with the necessary amount of work hours for them to be finished.
5. Multiply Work Hours by Relevant Payment Rate	According to the level of expertise assigned to each of the work tasks, work hours must be multiply by the payment rates to determine the costs related to task completion.
6. Combine Cost of each Task for Total Estimate.	The combination of all the costs related to the completion of tasks and activities will result in the Total Estimate for the Preconstruction Services for a particular project.

Once the scope of work is developed and defined by each department/division, the activities related to the scope of work can be organized into a hierarchy, which can be used to generate a work breakdown structure (WBS). The WBS provides an orderly classification of the particular work tasks for each functional level and a time reference for when those activities should occur during the PCS phase. The classification of each functional level and their respective tasks allows work to be properly identified, managed and controlled.

Assigning Level of Expertise

Work tasks require different levels of expertise in order to be properly accomplished. The next step after defining the work tasks to be completed is to assign the staff that will be responsible of the completion of each task. The staff should have the skills and the level of expertise required to successfully complete each of the assigned tasks. Levels of expertise can be distinguished in many ways, but are traditionally defined by pay rates.

Assigning Hours to Work Tasks

Task completion requires time and resources. The amount of time required for the available resources to complete the task is related to the complexity of it. Those tasks that are highly complex will require more work effort hours.

Uncertainty

An estimate being a prediction of the probable costs related to complete specific tasks, a degree of uncertainty its part of its nature. Uncertainty is directly related to the complexity of the task.

The degree of complexity for routine and low complexity tasks is low, but that it's not the case for new or uncommon tasks that carry a higher level of complexity. Estimates ranges are bound to uncertainties, therefore high complexity tasks will require wider estimate range due to a higher degree of uncertainty. In this situations to properly assign the work effort hours for those tasks it is recommended the use of three point estimation which combines the minimum, most likely and maximum values from the range estimate into a weighted average of hours [16].

In order to assist faculty who are interested in implementing the results of this paper and effectively teaching Pre-Construction cost estimating to their students, an abbreviated syllabus of a Pre-Construction Services course is included as Table 4. The abbreviated syllabus can be used as an example for faculty who are interested in developing Pre-Construction cost estimating courses. The proposed topics to be included in the course are presented earlier in the paper in Table 2.

Table 4: Abbreviated course syllabus (Gransberg, 2010)

Course Syllabus
Preconstruction Services

Prerequisites: Cost Estimating I

Materials:
All students will be required to provide an architectural and engineering scale, and a calculator. Students are required to bring these tools to each class period for use in the practical exercises and exams.

Course Description:
Advanced building and heavy civil estimating is designed to introduce students to the complete estimating process and enhance their ability to organize early estimates as part of the preconstruction services furnished by construction managers. Students will be introduced to feasibility, conceptual, mechanical, and electrical estimating. Additionally, students will be introduced to advanced computer applications as they pertain to estimating.

Course Objectives:
1. To understand the role of the constructor and its collaboration with design professionals and owners during the preconstruction phase on projects delivered using traditional (Design-Bid-Build) and integrated project delivery (Construction Manager-at-Risk, Construction Manager as Agent, and Design-Build).
2. To develop the ability to estimate at all levels including feasibility, conceptual, and guaranteed maximum price with contingencies, and understand the concepts, roles and responsibilities of the estimator in each type.
3. To understand the cost implications of safety, quality management, sustainable design and construction, constructability, and other administrative programs and how they are accounted for in the estimate. Additionally, the ethical issues that confront the estimator will be covered.
4. To understand how to develop subcontractor plug number estimates based on building codes and standards.
5. To apply oral and written communications skills during the preparation of feasibility and conceptual estimates as well as project proposals.
6. To apply the principles of sustainable construction and building information modeling to projects during the preconstruction phase.

Conclusions

The approach of this paper is the implementation of preconstruction services concepts and their respective cost estimating methodologies as part of an undergraduate and graduate construction engineering management curriculum due to the importance and consequences of overlooking PCS costs. Traditionally, maximizing cost savings philosophy has been the norm, which is not wrong, but it can be improved to achieve better results. The problem with the cost savings philosophy is not the "stop spending unnecessary funds" per se, but the selection and decisions

of where to save the money. Therefore, the decision should not be to save money in every possible way during the preconstruction phase, instead it should be spend the money wisely and with certainty in the essential activities and tasks to ensure quality PCS. Prior studies have demonstrated that spending the necessary resources in preconstruction activities enhances the ability to control costs during preconstruction development and furthermore during the construction phase. Consequently the goal that every owner should thrive to achieve is the development of high quality construction documents that ensure and increase cost certainty in the construction phase. This means that design fees should be viewed as an investment by owners in order to properly manage their costs during the project lifecycle, reduce risks, and obtain cost certainty to develop a high quality and successful project.

The significance of having construction cost certainty is the capability of reducing the risk of cost growth during construction. Cost certainty is directly related to the quality of design and construction documents. Therefore design budgets cannot be underestimated causing the overall quality of the project to be poor and insufficient. It does not mean that higher fees will guarantee a superior design, but a properly balanced budget can allocate the necessary resources to achieve the best possible solution, which will translate in superior construction documents. Estimating and spending the required amount of funds in the development and design of a project will result in an increase in the probability of its success.

To properly estimate the required amounts of funds for preconstruction services, this paper proposes to incorporate the following estimating methods into the construction engineering and management curriculum: Top-Down estimating, Bottom-Up estimating, and Functional Level estimating. A combination of the estimating methods is recommended in order to improve the accuracy of the estimates that depend on the amount of information available during planning, programming and preliminary design, final design, and advertisement and award. The accuracy of the estimate will result in the assignment of the necessary funds to develop and design high quality construction documents which will ultimately conclude in the ease and success of the construction phase. Accurate budgets will improve design and increase the certainty of construction costs, which leads to reductions in cost growth due to a decrease in contract modifications such as change orders. This paper demonstrated the importance of accurately estimating preconstruction costs and proposed a framework to assist engineering educators to integrate the subject into the required curriculum in Construction Engineering and Management programs.

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