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An order acceptance strategy under limited engineering man-hours for cost estimation in Engineering–Procurement–Construction projects

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Abstract

Accurate cost estimation is essential for any Engineering–Procurement–Construction (EPC) contractor accepting profitable projects because the project price is determined prior to receiving the contract. Therefore the contractor needs to ensure engineering man-hours (MH) in order to estimate project costs accurately as well as carry out the accepted orders. In this paper, we develop MH based order acceptance strategies and investigate their effects on the total expected profit through a long-term operation in EPC projects under a competitive bidding situation. To this end we build a simulation model describing relations among the volume of MH for cost estimation, accepted orders, revenues, and profits in EPC projects. Using our model, we show that the strategy, which maintains the appropriate balance of MH for cost estimation and project execution under the variability of accepted orders with competitive bidding situations, improves the total expected profit in EPC projects.

Keywords: Engineering and construction; Bidding; Cost estimation; Man-hour constraint

1. Introduction

Although there are various types of project contracts, the importance of Engineering–Procurement–Construction (EPC) projects (Ranjan, 2009; Towler and Sinnott, 2008; Yeo and Ning, 2002) is widely recognized in the fields of construction, civil engineering, plant engineering, and so on, because of the increasing client requirements for reduced project cost and for a shorter schedule. In EPC projects, the contractor has the sole responsibility for project cost, quality, and schedule under a fixed-price, which is determined before the start of the project as a lump-sum contract. Thus a reduced project cost and shorter schedule are expected as Ranjan (2009), Lotfian et al. (2010), and Jinru (2011) stated.

In EPC projects, a contractor is usually selected by a client through a competitive bidding process (Helmus, 2008; Ioannou and Leu, 1993; Rothkopf and Harstad, 1994). Namely, the client prepares a Request For Proposal (RFP) for the order and invites several potential contractors to submit bids. The client evaluates contractors on the basis of the multi-attribute bid evaluation criteria, such as bidding price, past experience, past performance, company reputation, and the proposed method of delivery and technical solutions (Helmus, 2008; Kerzner, 2009; Watt et al., 2009). Then, the client basically selects the contractor who proposes the lowest price if there is not much difference in other criteria. The selected contractor undertakes a series of tasks including detail engineering, procurement, and construction by directing and coordinating subcontractors within the limits of the predetermined budget and according to the predetermined schedule.

Since the contractor takes a significant risk with the project in the EPC contract, it is necessary for any contractor to determine the bidding price based on a precise estimation of its project cost

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by defining the project in as much detail as possible. If the contractor's bidding price is set higher than that of a competitor due to cost estimation error, the contractor could fail to receive the order. Conversely, if the cost estimation error results in an underestimation of the cost, the contractor would be granted the order; however, he would eventually suffer a deficit due to this order.

Cost estimation, however, is the highly intellectual task of predicting the costs of products or services to be provided in the future based on the analysis of the current client's requirements. Therefore, experienced and skilled human resources, i.e., engineering man-hours of skilled engineers (hereafter referred to as MH), are required for accurate cost estimation. Those resources, however, are limited in any company; furthermore, once the orders are successfully accepted, the corresponding projects will also need considerable MH to carry them out at the following periods. If the contractor accepts many orders during a particular period and thus cannot secure a sufficient volume of MH for estimating cost accurately, the profits in the following periods would decrease. This is because the probability of accepting loss-making orders increases as the cost estimation accuracy decreases in competitive bidding (Ishii and Muraki, 2011). As a result, the contractor suffers unstable and low profits during the following several periods.

For these reasons, to maximize the expected profit through a long-term operation in EPC projects, it is important for any contractor to accept orders with careful consideration of the appropriate MH balance of the cost estimation and project execution. However, the competitive bidding brings uncertainty of the volume of accepted orders, and hence, most contractors usually try to accept as many orders as possible to accomplish their original target for the volume of orders, especially when the uncertainty is large. As a result, contractors tend to accept an excessive volume of orders which reduces the MH for cost estimation in the following periods and diminishes the profit through a long-term operation.

In this paper, we develop MH based order acceptance strategies and investigate their effects on the total expected profits through a long-term operation in EPC projects under a competitive bidding situation. We build a simulation model describing the relations among the volume of MH for cost estimation, accepted orders, revenues, and profits in EPC projects. Using our model, we evaluate the effectiveness of order acceptance strategies from the perspective of the total expected profit in EPC projects through a long-term operation. We then show that the total expected profit can be improved by the MH based order acceptance strategy which maintains the appropriate balance of MH for cost estimation and project execution through a long-term operation in EPC projects under the variability of accepted orders with competitive bidding situations.

2. Related Work

Order acceptance is the problem the contractor faces in determining whether to accept each order or not, and its objective is to maximize profits with production capacity limitations. As shown by Herbots et al. (2007), Slotnick and Morton (2007), Rom and Slotnick (2009), and Wang et al. (2013), a variety of research topics exist. The literature on the contractor selection by the clients usually assumes competitive tendering (Hatush and Skitmore, 1997; Watt et al., 2010). However, it is noteworthy that most of the literature dealing with the order acceptance by the contractor has assumed single tendering without competitive bidding, and it has also assumed no limitation of the volume of MH for cost estimation. In EPC projects, however, the contractor determines a bidding price based on the project cost estimated by the limited MH, and the clients basically select a contractor from bidders through the competitive bidding process, as this paper assumes.

A variety of studies, such as bidding theory, bidding model and auction design, have been conducted on competitive bidding (Ballesteros-Pérez et al., 2013). In particular, a number of papers regarding the competitive bidding strategy date back to Friedman (1956), who presented a method to determine an optimal bidding price based on the distribution of the ratio of the bidding price to cost estimate. However, the constraint of the volume of MH for cost estimation has not been studied in previous research; nevertheless the volume of MH affects the cost estimation accuracy and the expected profits from the accepted orders in EPC projects.

Regarding cost estimation accuracy, various types of research have been performed. Oberlender and Trost (2001) studied determinants of cost estimation accuracy and developed a system for predicting the accuracy of the estimated cost. Bertisen and Davis (2008) analysed costs of 63 projects and evaluated the accuracy of estimated costs statistically. Brunoe and Nielsen (2012) applied a statistical method for cost estimation for quotation purpose in Engineer-To-Order environment where cost estimation is resource intensive. In addition, several cost estimation methods and their accuracy have been studied. For example, Page (1996), Humphreys (2004), and Towler and Sinnott (2008) studied relations among cost estimation methods, cost estimation data, and their accuracy in the field of plant engineering projects. More importantly, Gerrard (2000), and Towler and Sinnott (2008) suggested that the cost estimation accuracy is positively correlated with the volume of MH for cost estimation. Ishii et al. (2011) studied the effect of the cost estimation accuracy and the relevant MH on the expected profits in EPC projects under competitive bidding situations. In addition, Ishii and Muraki (2011) studied the effect of the volume of accepted orders at each period on the total expected profit through a long-term operation under the MH constraint for cost estimation. However, they did not study the order acceptance strategy to gain a high profit in consideration of the appropriate MH balance for cost estimation and project execution through a long-term operation.

In EPC projects, the bidding price must be determined before the start of the project; thus the volume of MH for project cost estimation is clearly one of the major factors for determining the profitability of EPC projects. Those MH, however, are limited in any contractor; furthermore, once the orders are accepted, the corresponding projects will also need considerable MH to carry them out. Thus it is important for any contractor in EPC projects to execute an appropriate MH based order acceptance strategy, which maintains the appropriate MH balance for cost estimation and project execution, in order to