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Hierarchy probability cost analysis model incorporate MAIMS principle for EPC project cost estimation

Xiangbai Gu [a,b], Zhiqiang Geng [a], Wenxing Xu [a], Qunxiong Zhu [a,*]

[a] School of Information Science and Technology, Beijing University of Chemical Technology, Beijing 100029, China
[b] Sinopec Engineering Company, Beijing 100029, China

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ABSTRACT

Two new types of hierarchy probability cost analysis (HPCA) model incorporating money allocated is money spent (MAIMS) principle based on definite work breakdown structure (WBS) level for EPC (engineering, procurement and construction) projects are presented. The proposed models have skillfully solved dilemma to appropriate cost elements and maximize the efficiency of information for cost risk analysis. Macroscopic and microscopic risk analysis of the project cost elements are introduced for meaningful model input. The illustration of an actual bidding EPC project substantiates that proposed integrating HPCA-hierarchy MAIMS models have demonstrated effective and viable for EPC projects.

1. Introduction

Real-world experience and intuition both suggest that project costs depend on many factors including technical, organizational, and behavioral considerations. Unfortunately, today's typical probabilistic cost analysis assumes an "ideal" project that is devoid of the human and organizational considerations that heavily influence the success and cost of real-world projects. In the real world "money allocated is money spent" (MAIMS principle); cost underruns are rarely available to protect against cost overruns while task overruns are passed onto the total project cost (TPC). Realistic cost estimates therefore require an integrated probabilistic cost analysis that simultaneously models all components of the cost management strategy including budget allocation, psychological influences (such as overconfidence in assessing uncertainties and dependencies among cost elements), unexpected events, and other important considerations that are generally not addressed.

The following deficiencies in cost modeling and contingency management have been major contributors to both project high costs and overruns: (1) garbage input (Walker & Cox, 2003); (2) "money allocated is money spent" (MAIMS principle) (Gordon, 1997; Kujawski, Alvaro, & Edwards, 2004); (3) invalid mathematics such as using statistical methods arithmetically summing uncertain cost elements instead of Gordon (1997) and Kujawski et al. (2004).

In today's highly competitive business environment, it is therefore critical to improve the realism of cost estimation. Monte Carlo simulation is only a mathematical tool of PCA, it cannot compensate for "garbage in/garbage out" (GIGO) (Walker & Cox, 2003). Meanwhile, overconfidence is also commonly found in the assessment of probability distributions.

Alpert and Raiffa (1982) say: in every case, the spread of the tails of the distributions was too small, regardless of the definition of the extremes, and although feedback did improve the spread, it did not completely eliminate the overconfidence bias.

Winkler, Hora, and Baca (1992) suggest three reasons why it is useful to aggregate the judgments of multiple experts: (1) an aggregated distribution provide a better appraisal of knowledge than the individual distribution (a sample mean is better than one observation); (2) the aggregated distribution is sometimes thought of as representing some sort of consensus; (3) it is easier to use a single distribution for further analysis.

The evidence shows that whether expert or naive, many factors affect the calibration and goodness of probability assessments. Studies of non-expert subjects answering almanac questions, while not providing meaningful probability assessments, do provide insight into the cognitive strategies used in making subjective probability assessments. While most researchers agree that feedback and training are necessary, there is little systematic evidence on what types of feedback improve calibration, discrimination, and other measures of goodness. Few studies assess how effective training is at overcoming the biases caused by cognitive simplification mechanisms (Wilson, 1999).

As Hogarth mentions (Hogarth, 1987), "the success any judgmental strategy will necessarily depend on the extent to which it is suited to the characteristics of the tasks". He suggests the development of taxonomy of assessment task characteristics that could be used to select appropriate elicitation techniques. For the EPC

* Corresponding author. Tel.: +86 10 64426960; fax: +86 10 64437805.
E-mail addresses: guxb@sinopec.com.cn (X. Gu), gengzhiqiang@mail.buct.edu.cn (Z. Geng), zhuqx@mail.buct.edu.cn (Q. Zhu).

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projects, work breakdown structure (WBS) is easily considered as such candidate taxonomy for similar techniques.

In general, there are interrelationships among the cost elements because of their dependence on common factors such as state of technology, complexity, criticality, management, staff, and product development process (Browning & Eppinger, 2002). Risks faced in complex engineering projects on different cost elements are often correlated; ignoring correlation in statistical computations makes the spread of the cost distribution narrower than it should be (Kujawski et al., 2004). Failing to account for correlation therefore deceives the analyst by making an estimate appear less uncertain than it really is. So, the correlation between project-item costs is a critical factor in the estimation of total project cost uncertainty.

It is standard practice for EPC projects to allocate definite budgets to cost elements and maintain a budget contingency for dealing with unforeseen in-scope events. The MAIMS principle captures the fact that given this situation, cost under runs are rarely available to protect against cost overruns while task overruns are passed onto the total project cost. Gordon's (1997) numerical studies strongly indicate that a realistic PCA needs to account for the MAIMS principle. To deliver a successful project at an optimal cost, project management needs to allocate "reasonable" budgets to the cost elements and dynamically manage the contingency funds as a risk portfolio at the project level (Kujawski, 2002a, 2002b).

Building on all above consideration, the practical yet realistic and mathematically valid hierarchy integrated probability cost analysis models are proposed to remedy several shortcomings that are prevalent in today's PCAs and adversely impact project management. In Section 1 we reviewed some findings on cost overruns and potential solution for complex EPC projects. In Section 2 the work breakdown structure (WBS) model is advocated for EPC projects cost taxonomy. In Section 3 macroscopic and microscopic risk analysis of the project cost elements are provided, to make sure that input to the cost model is meaningful and realistic. In Section 4 integrating HPCA-hierarchy MAIMS models are proposed. Correlation matrix that accounts for correlations among cost elements by rank and subject, and its feasible verification procedure are recommended. Some mathematical properties of multi-variable statistical product and sums are reviewed, after that, improved hierarchy cost estimation models based on WBS and MAIMS principle are proposed. In Section 5 illustration of an actual bidding EPC project substantiates that proposed integrating HPCA-hierarchy MAIMS models have been demonstrated and verified. In Section 6 summary and conclusions are introduced.

2. WBS for EPC project

The EPC project WBS term is defined as: (1) A EPC project-oriented tree composed of engineering, procurement, and construction. The tree results from systems engineering efforts during bidding stage. (2) A WBS displays and defines the project, to be developed and/or executed. It relates the elements of work to be accomplished to each other and to the end project. (3) EPC project WBS can be expressed down to any level of interest.

Generically, the work breakdown structure is defining the solution to the problem in terms of EPC project. The WBS shows the hierarchical relationship of the EPC project. Within the scope of the WBS, the EPC contractor has flexibility to use the work breakdown elements to support on-going management activities, such as collecting project cost data, project budgeting, cost risk analysis, and cost estimating. So, WBS for EPC project can be defined and specified as follows in order to maximize efficiency of cost information: (1) level 0 is the entire project. For instance, integrated refinery complex. (2) Level 1 is the entire phase of the EPC, such as engineering and procurement (EP), engineering, procurement, and construction (EPC), procurement and construction (PC). (3) Level 2 is usually identified as a sub-phase of a project. Such as bulk material, tagged items for procurement; detail engineering, procurement service and manual/as built drawing for engineering. (4) Level 3 is usually directly identified as units or sub-units of a project. (5) Level 4 elements are the discipline of the project. For example, civil, process, piping, etc. (6) Level 5 elements are working package subordinate to level 3. For example, Air cooler. (6) Level 6 elements are elements subordinate to level 5 elements. For example, Air cooler H-1101. That is to say EPC project WBS applies to seven specific categories of EPC projects. Summaries of typical categories are provided in Fig. 1. Just as the project is defined, developed and executed throughout its life cycle, so is the work breakdown structure. The WBS will be developed and maintained throughout the project's life cycle.

The WBS provides the framework for delineating the areas of responsibility regarding scope, cost, schedules, quality, and for integrating total project requirements.

3. Macroscopic and microscopic view of the project cost risk

The PDFs provide a macroscopic (Kujawski et al., 2004) rather than a microscopic view of the project cost risk. They effectively model those factors or project characteristics that are ever present

L0	L1	L2	L3	L4	L5	L6
Project	Phase	Sub-Phase	Units	Disciplines	Working Packages	Activites
Project Name	E Engineering	1 Detail Engineering	11 - NHT / OCT Naphtha Hydrotreater / Octanizer	AR- Architectural	P.2.22.ME.01 Air Coolers	P.2.22.ME.01 H1101 Air Coolers
		2 Procurement Service	12 - RCD Reduced Crude Desulfirization	CV- Civil		
		3 Manual/As Built drawing	13 - RFCC Residence Fluid Catalystic Cracking Unit	EE- Electrical & Telecommunication		
	P Procurement	1 Tagged Items	20 - OFF-SITE Tankage	ME- Fixed Equipment		
		2 Bulk Material	21 - STM / PWG Steam System/Power Generation	HE- Heat Transfer Equipment		
	C Construction	1 Construction	22 - WTR / FIRE Water System/ Fire Fighting System	HV- HVAC		
		2 Pre-commissioning	24 - WWT Waster Water Treatment	IN- Instrumentation		
			31 - Instrument System	PI- Piping		
				PR- Process & Chemicals		
				PM- Process Machinery		
				SF- Safety & Fire fighting		
				ST- Structure		

Fig. 1. Typical EPC project work breakdown structure.