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International Journal of Project Management 28 (2010) 708–718

International Journal of Project Management

www.elsevier.com/locate/ijproman

Comprehensive evaluation for construction performance in concurrent engineering environment

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Received 4 May 2009; received in revised form 10 November 2009; accepted 12 November 2009

Abstract

As a reformation of work pattern, concurrent engineering (CE) is commonly regarded as a systematic approach to integrated, concurrent design of products and its related processes, including manufacture and support processes. In the past several decades, the application of CE in many industries including construction industry has brought about a great enhancement of productivity. On the other hand, the application of CE has also resulted in a series of problems due to the simultaneous execution of different work phases. Among these problems, performance evaluation in a CE environment is a serious one for decision-makers to determine whether CE should be adopted in their blueprint of innovation. In this paper, a new evaluation method for construction performance in a CE environment based on evidence theory is presented. Compared with existing evaluation methods, it can perfectly deal with some negative influences of CE, such as the diversification of evaluation objectives, incomplete information of evaluation objectives, variance of evaluation indexes. In order to illustrate the viability and adaptability of this method, an example of application is given by this paper.

Keyword: Comprehensive evaluation; Construction performance; Concurrent engineering; Evidential reasoning; Indexes system

1. Introduction

The conception of concurrent engineering (CE) was first introduced in R-338, a noted report presented by the institute of defense analyze (IDA) in 1988 (Winner et al., 1988). Since then, work pattern based on CE has become the chief choice for many enterprises—including construction enterprises—to reengineer their business process and carry out integrated management system which is composed of quality, career, health, safety and environment (Chen, 2007; Chimay et al., 2002).

Compared with traditional sequential engineering, CE is commonly regarded as a systematic approach to integrated, concurrent design of products and its related processes, including manufacture and support processes. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements (Ostwald and Jairo, 1997). As an engineering and management philosophy, which also deals with the life cycle issues of a product, the most distinguishing feature of CE is the multidisciplinary, cross-functional team approach. The application of this approach can reduce project cost and accelerate project progress. As a direct consequence, palpable improvement in quality, time, cost, etc. has been achieved by those enterprises that have applied CE (Chen, 2007). CE applications were reported to achieve a 30–60% reduction in time-to-market, 15–50% reduction in life cycle costs and a 55–95% reduction in engineering change requests (Fine et al., 2005).

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0263-7863/$36.00
doi:10.1016/j.ijproman.2009.11.004

While enjoying the enhancement of productivity, those enterprises also found that the implementation of CE has resulted in a series of problems due to the simultaneous execution of different work phases (Chen et al., 2006). CE complicates the management problem as it requires joint optimization of a more complex objective with a larger set of constraints. CE is based on the idea of carrying out as many stages of project operation concurrently as possible, rather than in a sequential order. It calls for the formation of a cross-functional team, which includes people from a wide range of departments. As decision-makers, group members in multi-discipline team usually come from different disciplines and have different discipline knowledge, thus their objectives are different (Chen, 2007; Fine et al., 2005). Furthermore, a series of issues, which are critical for the successful implementation of CE, including organization, technology, manpower, etc., must be changed to cater for the characteristics of CE (Chen et al., 2006; Chimay et al., 2002; Khafan and Anumba, 2000; Rosenblatt and Waston, 1999; Vincent and Gavriel, 1998). These works will definitely add extra cost to projects. Among these problems, performance evaluation in a CE environment is a serious one for decision-makers to determine whether CE should be adopted in their blueprint of innovation. However, construction performance is not easily amenable for measurement in a CE environment due to the following factors:

- Diversification of evaluation objectives. Work teams with different discipline knowledge and backgrounds will work together in a CE environment, thus their objectives are diversified. In this case, performance evaluation belongs to nonhomogeneous decision-making problem and many existing methods are not equal to the evaluation requirements (Chen et al., 2006; Chen, 2007).
- Incomplete information of evaluation objectives. Due to the simultaneous execution of different work phases in a CE environment, operation mechanism of project organization will become fuzzy and complex. So it is difficult for decision-makers to mine the real and useful information from original data (Brookes and Backhouse, 1997; Chen et al., 2006).
- Uncertainty and vulnerability of evaluation objectives. Interactions among different departments in a CE environment will increase largely. So the interface among departments is becoming vaguer and vaguer which may bring more conflicts and disputes accordingly (Evbuomwan and Anumba, 2000; Koufteros et al., 2001).
- Variance of evaluation indexes. Diversity of evaluation index is a natural characteristic of the evaluation problem. In a CE environment, this problem is intensified by the constant change of evaluation index and the continual interactions among different departments. Therefore, keeping consistency of evaluation index should be paid a lot of attentions and be processed perfectly by appropriate tools (Nicholas, 2001; Zhang et al., 2006).

It can be seen from what is discussed above that performance evaluation in a CE environment is a comprehensive evaluation problem which is at the same time a nonhomogeneous decision-making problem. When facing such evaluation puzzle, choosing an appropriate evaluation method is important to the objectivity and veracity of evaluation result. With regard to evaluation methods, great progress has been achieved in the past several decades, which can be summarized as follows:

- *System simulation method*: This method uses advanced computer technology to simulate the operation process of a complex system. Then analysis of evaluation objective will be given based on the simulation result. Computer program language, such as MATLAB, GPSS and SLAM, can be used to realize this process (Kittock, 1993; Lu et al., 2005).
- *Information theory method*: This method originally came from information entropy theory. It deems that the information contained in a certain activity is an invariant, so it can be used to reflect the real information of evaluation objective by excluding man-made factors (Jiang, 1996; Kryszkiewicz, 1998).
- *Grey theory method*: It was first put forward by professor Deng (2005), and a further research emphasized on grey (fuzzy) clustering was made by professor Liu. This method can deal with the grey system which is an intermixture of ambiguous information and unambiguous information (Dang et al., 2005; Liu and Lin, 2006).
- *Artificial intelligence method*: This method is an improvement of artificial neural net arithmetic. It is widely utilized to evaluate an uncertain system. Self-learning and self-adaptation is the main characteristic of this method (Dai et al., 2008; Jennings et al., 1998).
- *Dynamic evaluation method*: This is a comprehensive evaluation method supported by multidimensional time series, its time parameter is changing continually along with the evaluation progress (George and Terranova, 1999; Huang et al., 2000).
- *Interactive multi-objective evaluation method*: It is an intelligent method used to deal with the combination of subjective and objective, knowledge acquirement, accumulation of evaluation specimen and flexibility of decision making (Xu, 2002).
- *Rough sets method*: This method was originally put forward by Pawlak (2002); it is often used to deal with the problem featured with fuzziness and uncertainty (Sarkar, 2002).
- *Data envelopment analysis (DEA)*: This is a nonparametric method that developed from Farell measurement (Farell, 1957). This method is often used to evaluate the achievement of decision making unit (DMU). It can maintain the original value of in–out unit and project DMU onto former side by using mathematic programming. The relative efficiency of DMU can be attained by measuring the deviation between DMU and DEA (Qiu and Ye, 2005; Wei and Zhou, 2006).