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The impact of uncertainty and ambiguity related to iteration and overlapping on schedule of product development projects

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Abstract

Overlapping and iteration stemming from concurrent engineering are fundamental features of product development (PD) projects. They may not only reduce project duration but also create process uncertainty and ambiguity. We propose that the iteration and overlapping are the main causes of uncertainty and ambiguity in the PD process. Based on discrete-event simulation modeling and analysis with Arena software, our empirical research provides a quantitative method to reveal how uncertainty related to iteration and ambiguity related to overlapping impact on project schedule. In the simulation model, we use four variables to characterize uncertainty: iteration probability, iteration length, number of iterations and activity's learning curve effect. And different sequential and overlapped process structures are used to describe the variable of ambiguity in the model. Propositions regarding the reduction of uncertainty and ambiguity by controlling iteration and overlapping are derived. Simulation experiment results yield and reinforce several managerial insights, including: the relationship between uncertainty or ambiguity reduction and the complexity of iteration or levels of overlapping; and how to control project schedule and hedge the risk resulting from overlapping and iteration.

Keywords: Product development; Project management; Concurrent engineering; Overlapping; Iteration; Simulation; Scheduling

1. Introduction

To gain competitive leverage, more and more firms that design and develop complex products are seeking to control uncertainty and ambiguity in their new product development (PD) projects (Loch and Terwiesch, 1998; Schrader et al., 1993). Information inadequacy about the characteristics of a PD process will result in uncertainty and ambiguity (Pich et al., 2002). Unlike manufacturing processes, an important characteristic of PD processes can be described with terms like "creative," "innovative," and "iterative" (Browning and Eppinger, 2002). The PD process is a complex network of interactions, of which iteration and overlapping of design activities are fundamental characteristics (Krishnan et al., 1997; Terwiesch and Loch, 1999). They may not only reduce project duration but also create uncertainty and ambiguity (Loch and Terwiesch, 1998).

Iteration refers to the repetition (or rework) of activities. It can be represented by *feedback loops* or *cycles* in the PD process. Iteration and rework are major drivers of project schedule overruns and associated risks (Cooper, 1993). Several authors have explored the sources of iteration in the PD process (Eppinger et al., 1994; Steward, 1981). Usually, the main sources of iteration in PD projects involve inherent coupling between activities, poor activity sequencing, incomplete activities, poor communication, input changes and mistakes (Lévárdy and Eppinger, 2009). Some of these causes of iteration are avoidable. Some types of iteration should even be encouraged so that the design process will converge more quickly, so they need to be planned and managed carefully (Eppinger and Browning, 2012).

There are three main methods for sequencing activities in a PD process: parallel, sequential and overlapping methods. Parallel structure means that without input–output interactions between them, activities may be executed simultaneously (Eppinger and Browning, 2012). A sequential process is utilized for sequencing dependent activities with input–output information between

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them (see Fig. 1(a)). One approach to accelerate such a sequential process is the overlapped process (Fig. 1(b)), in which the sequential activities are partially overlapped: the downstream activity (i.e., the successor activity) starts before the upstream activity (i.e., the predecessor activity) is completed (Eppinger and Browning, 2012). Overlapping may be achieved by careful scrutiny of each finish-to-start dependency (Krishnan et al., 1997). Although both parallel process and overlapped process are methods of concurrent engineering, they are different in the following aspect. The parallel activities are independent and there is no information exchange among them. The coupling between upstream and downstream activities is removed, resulting in a parallel process (Krishnan et al., 1997). For example when upstream activity A is finished, two independent downstream activities B and C can start simultaneously, so activities B and C are parallel. But overlapping is the process of starting the downstream activity before completing the upstream activity (Terwiesch and Loch, 1999). The overlapped activities are interdependent (see Fig. 1(b)).

For accelerating the PD process, Yang et al. (2012) proposed the *overlapped process with lead-risk*, in which interactions between coupled activities may raise rework risk (see Fig. 1(c)). In order to further accelerate the PD process, the *parallel overlapped process with lead-risk* can be utilized through integrating the parallel and overlapping methods. As shown in Fig. 1(d), the downstream activity may be further decomposed into several smaller sub-activities so that they can be executed simultaneously (i.e., parallel process) for reducing project duration. Although overlapping and iteration in concurrent PD projects can accelerate the PD process, they also generate uncertainty and ambiguity (Eppinger et al., 1994).

Schrader et al. (1993) argued that uncertainty and ambiguity are dissimilar concepts in projects. Uncertainty refers to the situation that all decision variables relevant to the completion of project tasks are assumed to be known in advance, although their accurate values may be unknown. In the concurrent PD process, uncertainty related to iteration involves iteration probability, iteration length, number of iterations and activity's learning curve effect. Ambiguity is a state in which the project manager does not exactly know the relevant variables and their dependency relationships (Schrader et al., 1993). Ambiguity refers to a lack of awareness of the project team about certain states of the project or causal relationships between coupled activities in the process structure (Schrader et al., 1993). Ambiguity may result from inadequacy of information which may force the project manager to select a low-level concurrent process (e.g., Fig. 1(a) and (b)). In other words, the sequential or low-level overlapped process imply that project managers lack awareness about certain states of the PD process or dependency relationships between coupled activities. Thus, different process structures can reflect different levels of ambiguity.

The difference between uncertainty and ambiguity has been explored by several authors (Gil et al., 2008; Larson and Gobeli, 1988; Pender, 2001; Pich et al., 2002). Although previous researches bring considerable insights into the uncertainty and ambiguity, a quantitative analysis method is ignored. In another word, there is a lack of quantitative analyses on the impact of overlapping and iteration on project schedule for reducing uncertainty and ambiguity in PD projects. So, this paper seeks to explore the following questions.

1) How to calculate the impact of uncertainty related to iteration and ambiguity related to overlapping on project duration using simulation?
2) How to control uncertainty and ambiguity associated with overlapping and iteration in a concurrent PD project in order to reduce project duration and schedule risk?

To address the above issues, we utilize simulation model to analyze how uncertainty related to iteration and ambiguity related to overlapping impact on project duration. We derive several propositions regarding the reduction of uncertainty and ambiguity by controlling iteration and overlapping. The rest of the paper is organized as follows. In Section 2, we review the literature on uncertainty/ambiguity and iteration/overlapping in PD processes. We discuss in Section 3 the characteristics of uncertainty and ambiguity in concurrent PD projects. In Section 4 an empirical study of Chinese IT industry is conducted and a framework of simulation experiment is designed. We perform a series of simulation analysis to derive several propositions pertaining to the reduction of uncertainty and ambiguity by controlling iteration and overlapping in Section 5. We conclude the paper in Section 6.

2. Literature review

2.1. The complexity, uncertainty and ambiguity in PD projects

New product development projects are growing more and more complex. Both at the micro- and macro-level, project managers accumulate an exponentially increasing amount of information during PD processes. So project managers must continue to develop techniques for mastering the vast amount of information

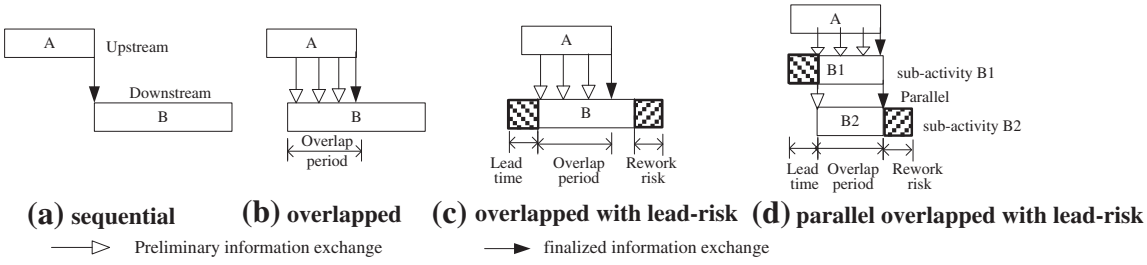

Fig. 1. Sequential and overlapped processes.