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A simulation model to study the impact of early information on design duration and redesign

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Abstract

In the design process, it is common to utilize early information from precedent activities to shorten the project duration instead of having to wait for the confirmed parameter values to arrive after full analysis. However, the estimated preliminary parameter might be different from that obtained after the full analysis. Consequently, redesign may be needed in downstream activities to correct this discrepancy. Total amount of induced redesign may adversely impact loss of productivity and overall design completion. Furthermore, redesign requires additional resources which may exaggerate the project completion for a project with limited resources. This study presents a simulation model to describe the effect of utilizing early information on redesign and total design duration. The paper characterizes the reduction in project duration while accounting for the impact of redesign through sensitivity studies of the parameters of the simulation model. The sensitivity studies would provide valuable insight that project managers can take into account when utilizing early information in design.

Keywords: Design process; Design parameters; Early estimation; Redesign; Simulation model; Sensitivity study

1. Introduction

A construction project involves both design and construction tasks. Increasing attention has been paid to the control of design schedule since construction is commonly delayed by the lateness of design deliverables including drawings, calculations, and reports (Wang et al. 2006). Difficulties arise in the design phase since these activities are highly and even cyclically dependent on each other for design information (or parameters; a parameter that an activity "column design" produces might be cross-sectional area, or reinforcement details). Moreover, diverse parties across organizations are typically involved in various activities in design leading to complexity in design coordination. Similar findings have been described by Alarcón and Mardones (1998). Their study shows that the main problem in design is the lack of information and the designers do not deliver enough information on time to the construction field and to other participants in the design process which result in a chaotic scene. These dependencies inadvertently lengthen the design process.

Time to complete a project is of great importance in today's competitive market especially where LD (liquidated damages) is very high. Getting early information from precedent activity(s) can speed up the design process and reduce the project duration (Krishnan et al. 1997; Bogus et al. 2005; and Maheswari and Varghese 2005). However, this is accompanied by the possibility of redesign downstream because the early information utilized may differ from that obtained after full analysis. Peña-Mora and Li (2001) proposed strategies for starting downstream activity early through overlapping with upstream activity by dividing into various intervals in terms of upstream evolution and downstream sensitivity. Bogus et al. (2006) also described overlapping strategies with an aim to minimize redesign in downstream activities. The abovementioned researches considered only single dependencies, i.e. a pair of dependent activities. With multiple dependencies it is very complicated to account for impact of redesign. Effect of this redesign on the overall project completion is an important consideration in

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project planning. Moreover, the impact of redesign is characterized by various design factors when using early information. These are estimability, time to do estimation, probability of redesign based on accuracy of estimated parameters, and redesign duration for each activity.

Consequently, this study seeks to quantify the time saved using early information (through estimation) and the additional time subsequently needed for redesign considering multiple dependencies between activities. Particularly, the study examines the sensitivities of these project metrics to the various design factors related to using early information. From this a project performance matrix is built to provide a better insight into the combination of design factors that allow the use of early information to be exploited without compromising project performance. To achieve this, the simulation technique has been utilized to model the design process including redesign. The simulation model explicitly considers the interaction of information flow among the activities and measures the loss in productivity due to redesign. The amount of redesign that can be expected for different degrees of concurrencies is studied through a case study involving 83 design activities for an oil refinery project.

The following section provides some literature reviews relevant to the described research work. After that the concept of estimability has been illustrated accounting for redesign, followed by a description of the discrete event simulation model utilized to represent the use of early information and redesign. Then a case study has been provided utilizing early information and some sensitivity studies have been done to characterize project performance metrics for different design parameters relating to use of early information. Finally, a conclusion section summarizes the contribution and findings of this paper.

2. Some concerns in scheduling the design process

Steward (1981) first developed Design Structure Matrix (DSM) to represent task dependencies in product design. DSM has been found to be very effective in identifying and managing information flows between activities, and ordering tasks for greater concurrency and reducing cyclical loops (Oloufa et al. 2004; Pektaş and Pultar 2006; and Collins et al. 2009). The DSM is a square matrix with equal rows and columns corresponding to the number of design tasks. The design tasks are listed in rows and columns sequentially in the same order and a mark is placed in the matrix if there is an information flow (or parameter dependency) from one task to the other (see Table 1 as an illustrative example).

Table 1
DSM in order to show the dependency.

Activity	A	B	C	D	E	F	G
A							
B	x			x			
C	x	x					
D	x		x				
E		x		x			
F			x				
G		x			x	x	

Although, DSM can produce an appropriate order of design tasks to account for information dependency and minimize feedback loops, it is typical that the design schedule strictly following this order by waiting for confirmed parameters from preceding design tasks far exceeds the duration of the project. Though Maheswari and Varghese (2005) compressed project schedule with overlapping, they ignored the impact of redesign while utilizing preliminary information. In practice, it is common to utilize early information from precedent activities in order to significantly shorten project duration (Krishnan et al. 1997 and Maheswari and Varghese 2007). This introduces the possibility of redesign for succeeding activities if the estimated (early) parameters are found to deviate substantially from the subsequent confirmed parameters.

Krishnan et al. (1997) increased the concurrency by overlapping activities and modeled rework iteration by revising downstream activity until upstream information had been finalized. Bhuiyan et al. (2004), Bogus et al. (2006), and Ouertani (2008) have done similar researches to further extent the overlapping concept more elaborately. However, their models are applicable for a pair of sequential activities but are cumbersome to model the interaction of multiple activities and incorporation of early information and redesign. Maheswari and Varghese (2007) have modeled design iteration for activities involved in a loop. But, they did not quantify the impact on project duration as a result of redesign. Modeling early information as a means of greater concurrency and accounting for redesign for the overall design project remains a big concern in practical applications.

3. Concept of estimability and redesign

Parameters produced by design activities have various attributes which help in understanding the requirements in a design process (Chua and Tyagi 2001). Three attributes that play an important role in scheduling are estimability, volatility, and states of parameter. A design activity is estimable if parameter value produced by this activity can be estimated so that the estimate could be utilized as early information for downstream activities instead of having to wait for confirmed information after full analysis. Early information is tentative preliminary value of parameter produced by an activity. The estimation might be done from past experiences, design results of similar projects, common rule-of-thumb values, or any other base line data. Accuracy of estimated parameter is associated with possibility of redesign in downstream activities.

Volatility measures the possibility of the parameter value being changed due to external environment such as clients, consultants, legislative requirements and the likeliness of design change from the upstream activities. Often times, external factors affecting design process are entirely unpredictable beforehand so that it is beyond the scope of the present study to account for its effects in the schedule. On the other hand, the likeliness of design change for an activity depends to a large extent on whether estimated or confirmed information/parameter has been obtained from its precedent. The greater the volatility, the greater will be the possibility that the confirmed parameter value differs significantly from the estimated so that