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Decision Support

Optimal testing strategies in overlapped design process

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ABSTRACT

Testing is an important activity in product development. Past studies, which are developed to determine the optimal scheduling of tests, often focused on single-stage testing of sequential design process. This paper presents an analytical model for the scheduling of tests in overlapped design process, where a downstream stage starts before the completion of upstream testing. We derive optimal stopping rules for upstream and downstream stages' testing, together with the optimal time elapsed between beginning the upstream tests and beginning the downstream development. We find that the cost function is first convex then concave increasing with respect to upstream testing duration. A one-dimensional search algorithm is then proposed for finding the unique optimum that minimizes the overall cost. Moreover, the impact of different model parameters, such as the problem-solving capacity and opportunity cost, on the optimal solution is discussed. Finally, we compare the testing strategies in overlapped process with those in sequential process, and get some additional results. The methodology is illustrated with a case study at a handset design company.

1. Introduction

For most product development projects, the initial design inevitably contains design problems, such as mismatches with customer needs, technical design faults, or issues regarding manufacturability and maintainability of the product (Thomke and Bell, 2001). Testing, which is a primary way to detect and resolve these problems, is central to product development (Thomke, 2003).

Typically, tests are carried out in several stages with increasing fidelity (Wheelwright and Clark, 1992; Thomke, 2007). For example, as shown in Fig. 1, there are four stages in the development of mobile phones: *Concept Design*, *Detail Design*, *Tooling Fabrication*, and *Volume Production*. Following these development stages, different testing activities are carried out. *Concept tests* are performed by asking customers to evaluate the 3D drawings or digital mock-ups, making sure that the design meets their requirements. *Design Evaluation Tests* are carried out separately in each subsystem of the product, to ensure compliance with product specifications and remove variations. In *System Tests*, physical prototypes are used to improve the overall performance of the product.

Due to the accumulative and proliferous nature of design problems, the outputs of an upstream stage need to be tested extensively before releasing them to downstream stages. Inadequate testing would allow design problems to propagate, and finally deteriorate product's quality. On the other hand, testing also incurs time and cost. Too much testing at one stage would impede the project's progress and increase development costs. Hence, the key issue is how to optimally schedule various testing activities along the design process so that the highest project performance, in terms of time, cost and quality, can be achieved.

Some models have been developed to determine the optimal scheduling of tests and/or reviews for product development projects. For example, Ha and Porteus (1995) developed a dynamic program to determine the optimal frequency of upstream design reviews within two overlapped design phases. Dahan and Mendelson (2001) modeled the concept testing as a probabilistic search process and proposed an extreme-value model to determine the optimal number of tests for concept development. Thomke and Bell (2001) developed a model to decide the optimal timing, frequency and fidelity of sequential tests. They showed that the optimal testing strategy should balance several things, including the testing cost and the cost of redesign. Test scheduling problem has been studied extensively in software development literature (see e.g. Yamada et al., 1995; Xie and Yang, 2001; Dai et al., 2003; Pham and Zhang, 2003; Serich, 2005; Tamura and

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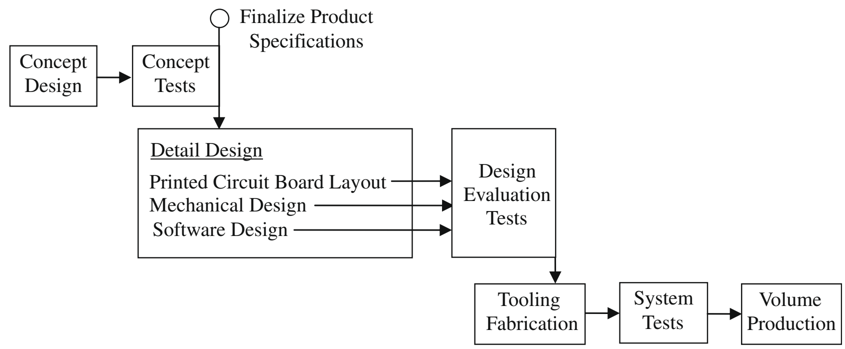

Fig. 1. Typical testing stages in the development of mobile phones.

Yamada, 2006). These models have clearly shed light on the analysis of test scheduling problem. However, they focus on the testing policies at one design stage and do not take into account the multi-stage nature of testing process.

Ahmadi and Wang (1999) explicitly modeled the multi-stage review process, and examined how to optimally schedule reviews and engineering resources along the design process so as to achieve the required level of process confidence at minimal development cost. While their work is useful for managing the sequential process, the solutions and insights they get may not be applicable to overlapped design process where downstream stages start before the completion of upstream stages. It is worthwhile to investigate the testing strategies in overlapped design process, since overlapping development stages has become a common mode of product development (Terwiesch et al., 2002; Roemer and Ahmadi, 2004; Joglekar and Ford, 2005; Yassine et al., 2008), and since the testing strategies combined with overlapping policies may affect project performance differently compared with testing strategies in the sequential process.

Recently, Lin et al. (2008) built a simulation model for overlapped iterative product development. Given a set of testing strategies and overlapping policies, their work can be used to compare these solutions and identify which one is best. However, in their model, verifying the optimality of a solution requires enumerating all possible solutions. Thus, for problems with continuous decision variables, it is unlikely to get a good solution quickly and efficiently. Unlike their research, we built an analytical model to examine the test scheduling in overlapped process, and to help management derive the optimal testing and overlapping strategies. Moreover, analysis of our model yields several useful insights (Propositions 1, 2, 3, 4 and Corollaries 1, 2, 3) which cannot be derived from their model.

The rest of this paper is organized as follows. In section 2, we formally model the problem of test scheduling for overlapped process. The optimal policies are characterized in section 3. In section 4, we illustrate the methodology with a case study at a handset design company. Section 5 concludes this study.

2. Model formulation

2.1. Overview of the model

Considering the product development process with two design stages, we call the first stage *upstream* and the second *downstream*. The downstream stage depends on the output information from the upstream stage. Fig. 2a shows the product development process where testing and overlapping are not applied. Clearly, the completion time for this process is: $T_0 = T_1 + T_2$, where T_1 and T_2, respectively, denote the regular durations for performing initial development of upstream and downstream stages.

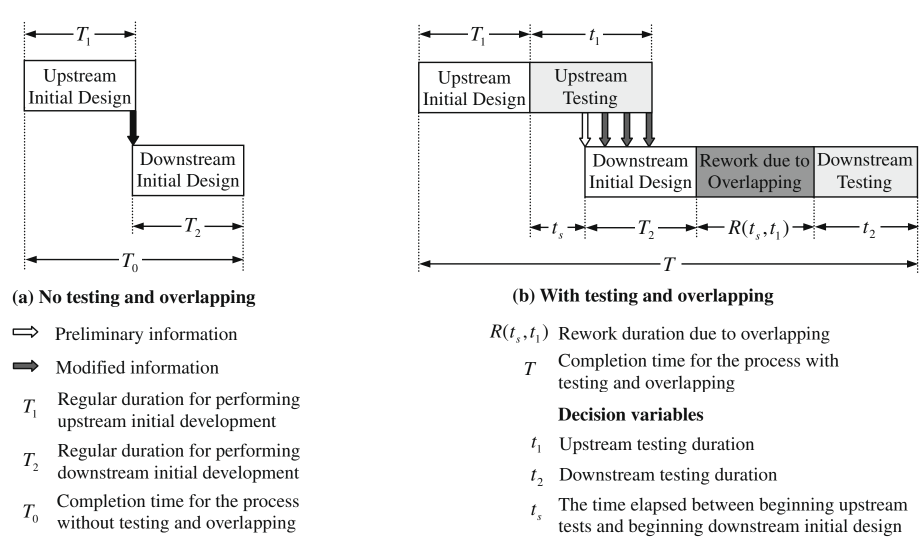

Fig. 2. Product development processes.