



A systematic literature review of software quality cost research

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ABSTRACT

Software quality costs have not received as much attention from the research community as other economic aspects of software development. Over the last three decades, a number of articles on this topic have appeared in a range of journals, but comprehensive overviews of this body of research are not available.

For the detailed review of software quality cost research presented in this article, we collect 87 articles published between 1980 and 2009 in 60 leading computing journals. We study the distribution of these articles across research disciplines and journals as well as over time. Moreover, we identify the predominant researchers in the software quality cost domain and the related research clusters. We also classify the articles according to three properties, namely, research topic, research scope, and research approach. This categorization enables us to identify aspects emphasized by previous research on software quality costs and to point out promising future research directions. Our review shows that prevention costs have gained the least attention, in spite of their big cost impact. It also reveals that only one article has targeted multiple companies. Further, we observe that many articles do not empirically validate their findings. This is especially true for those articles dealing with an entire firm.

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1. Introduction

For decades, users of software solutions have been suffering from poor solution quality (Whittaker and Voas, 2002). Over the years, quality has emerged to be a key issue in software development (Pralhad and Krishnan, 1999). Software vendors have attempted to tackle this issue by adapting concepts from other engineering disciplines, such as manufacturing (Antony and Fergusson, 2004). There, approaches ranging from Total Quality Management over Six Sigma and Kaizen to Lean Production have led to significant gains in productivity and quality. To attain similar results in software development, many of these concepts have been adapted and tailored to its characteristics (Middleton and Sutton, 2005). In this quest for higher productivity and quality, the economics of software engineering are of particular interest (Boehm, 1981). While some economic aspects, such as software development effort estimation (Jorgensen and Shepperd, 2007) and software process improvement (Hansen et al., 2004), have frequently been discussed, others have received less attention. Indeed, little research has specifically been devoted to those costs which are “incurred in the pursuit of [software] quality or in performing quality-related activities”

(Pressman, 2010, p. 407). This is remarkable, because software vendors typically spend 30–50% of their development budget on defect detection and correction (Ebert and Dumke, 2010).

In most engineering disciplines, literature studies summarizing the latest research results on quality costs are regularly published (e.g., Williams et al., 1999; Schiffauerova and Thomson, 2006). To the best of our knowledge, this is not the case in software engineering; no review prior to ours has in particular been devoted to software quality cost research. However, several studies published in the broader field of software quality and software economics have also covered some quality cost aspects. For instance, the survey of software quality assurance research by Rai et al. (1998) considers software quality costs among other economic aspects, and Jorgensen and Shepperd (2007) systematically review work on software development effort estimation including approaches applicable to software quality cost estimation.

This article tries to close this research gap. It is exclusively devoted to software quality cost research. Our objective is to systematically review and structure the existing body of research on software quality costs and to identify areas for future research. We analyze 87 articles published between 1980 and 2009 in 60 leading computing journals for answering eight research questions. These research questions are directed at the research domain in general as well as at specifics of the existing research, regarding the software quality cost categories examined, the scope of investigation, and the research approaches employed.

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The main contributions of this systematic literature review are thus two-fold: (1) We systematically gather and discuss domain-relevant articles, covering 30 years and a large number of computing journals. (2) By answering our eight research questions, we identify aspects emphasized by prior research and areas that future work should address.

The remainder of this article is structured as follows: In Section 2, the eight research questions of our systematic literature review are presented. Next, Section 3 introduces the review method applied and the classification scheme used. The results of the review are then discussed in Section 4, answering the research questions formulated. The article closes with Section 5, which sums up our findings and suggests areas for future research.

2. Research questions

Conducting any systematic literature review needs the postulation of research questions, which drive the entire research methodology (Kitchenham and Charters, 2007). In accordance with prior studies, such as Jorgensen and Shepperd (2007), Beecham et al. (2008), and Kitchenham et al. (2009), we postulate the eight research questions discussed in the following sub-sections to investigate the software quality cost domain.

2.1. Historical development

As in other engineering disciplines (Dale, 2003), the understanding of software quality has gone through different phases proposing different approaches for coping with the challenge of low quality and high quality-related costs (Whittaker and Voas, 2002; Karg and Beckhaus, 2007). Nevertheless, software quality remains low, while quality-related costs are high. In recent decades, software engineering economics in general (Boehm, 1981; Biffel et al., 2006) and software quality costs in particular (RTI, 2002) have moved into the spotlight. These developments, together with the need to cope with the high quality-related costs, motivate the assumption that the research intensity in the software quality cost domain may have increased in recent years. By proposing the following research question (RQ), we try to verify this assumption:

RQ 1. How did research on software quality costs develop over time?

2.2. Research disciplines

According to Glass et al. (2004), the field of computing consists of three research disciplines: *computer science*, *information systems*, and *software engineering*. While systems/software, systems/software management and organizational concepts are primarily addressed by the disciplines information systems and software engineering, the discipline computer science aims at mathematical aspects. Since the quality cost concept has originated in engineering management (Dale, 2003), it can be assumed that research on software quality costs is most commonly conducted within the disciplines information systems and software engineering. To check this assumption and to reveal which discipline is the most active one, we postulate the following research question:

RQ 2. Which discipline does most frequently publish software quality cost research?

2.3. Relevant journals

Previous investigations have shown that research on software engineering economics and quality management is published in several journals (Rai et al., 1998; Jorgensen and Shepperd, 2007). Software quality costs form a sub-domain of these two research

domains. Hence, it can be assumed that only in some of these journals research on software quality costs is published as well. Identifying these journals will provide a valuable reference to the research community. By answering the following research question, we provide a ranking of those journals:

RQ 3. Which journals do most frequently publish software quality cost research?

2.4. Predominant researchers

In most research domains, there is only a very small number of researchers who are highly active and thus shape the research domain (Jorgensen and Shepperd, 2007). Our goal is to identify these leading researchers and the research clusters they belong to. Knowing these researchers and the topics they work on helps to develop a better understanding of the research domain. We thus want to answer the following research question:

RQ 4. Who are the predominant researchers, and what are the related research clusters?

2.5. Research topics

Several topics and cost elements can be distinguished with regard to software quality costs. According to cost accounting theory, quality cost elements can be structured by different classification schemes (Horngren et al., 2008). For software development, the PAF (prevention, appraisal, and failure) cost scheme is the one most commonly applied (Galini, 2003; Karg and Beckhaus, 2007; Grottko and Graf, 2009; Pressman, 2010). The scheme distinguishes between three quality cost types related to corresponding activity types (Pressman, 2010):

- Prevention costs, i.e., costs for activities like quality planning and training which help to avoid future appraisal and failure costs;
- Appraisal costs, i.e., costs for appraisal activities like testing, control, and measurement; and
- Failure costs, i.e., costs for failure-related activities like rework, failure mode analysis, and corrective maintenance.

By classifying articles based on these cost types, we can provide an answer to the following research question:

RQ 5. Which cost types are the predominant topics of software quality cost research?

2.6. Research scopes

Quality management has a long history, and it has focused on different aspects and granularities (Whittaker and Voas, 2002; Yong and Wilkinson, 2002). The same holds for research on software quality costs, implying that it can be carried out at different levels (Williams et al., 1999). Some work focuses on the costs of one particular quality assurance activity, while other work operates at a coarser granularity level, e.g., work addressing the costs of all failure-related activities in a company. We wish to find out at which granularities research is conducted most frequently and thus propose the following research question:

RQ 6. What are the primary research scopes?

2.7. Research approaches

Usually, several research approaches are used to explore a research domain (Ahire et al., 1995). However, the approaches predominantly used can have a strong influence on the findings of the research domain as well as on its development, which is strongly

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