ORGANIZATIONAL CONTROL SYSTEMS AND SOFTWARE QUALITY: A CROSS-NATIONAL STUDY

Sanjay Gosain
Robert H. Smith School of Business
University of Maryland, College Park
College Park, MD USA
sgosain@rhsmith.umd.edu

David P. Darcy
Robert H. Smith School of Business
University of Maryland, College Park
College Park, MD USA
ddarcy@rhsmith.umd.edu

Anand Gopal
Robert H. Smith School of Business
University of Maryland, College Park
College Park, MD USA
agopal@rhsmith.umd.edu

Yossi Lichtenstein
IBM Research
Haifa, Israel

Abstract

This study explores the relationship between organizational control modes (behavior, outcome, and clan) and software quality. Much of the previous work on organizational control has examined the choice of modes given task characteristics. This research extends work in control theory by considering the impact of control modes on the increasingly critical organizational outcome of software quality. The research is set in the context of software development organizations in three of the largest software developing countries: India, Ireland, and Israel (the 3Is). A cross sectional survey of 400 software development organizations across the 3Is will be used to test the developed model. In addition to the theoretical contributions, the study will provide practical implications to support software project managers in making better organizational control choices.

Keywords: Software development, control systems, software quality, survey methodology

Introduction

The business use of information technology (IT) has become ubiquitous and IT is a key asset in gaining competitive advantage. Total IT expenditure worldwide soared from $175 billion in 1990 to $525 billion in 2000 (Bates et al. 2003). A critical component of this phenomenal growth is software. Globally, the market for systems integration and outsourcing, considered the pillars of the software services industry, were $125 billion and $100 billion respectively in the year 2000 (Bates et al. 2003). Given the sheer size and importance of the software industry, it is important for researchers to gain a better understanding of what drives value in software development. The central role assumed by software in organizational processes in industry places a premium on the quality of software produced (Prahalad and Krishnan 1999). However, achieving high software quality continues to be a serious problem, as evidenced by estimated costs of $59.5 billion due to software defects in the United States alone (Thibodeau and Rosencrance 2002). There is a lack of research that has examined the drivers of quality in software organizations (Osterweil 1996). We add to this growing literature by proposing and empirically validating a model of organizational controls that impact software quality.

Quality is a key performance outcome of software development activities and has not been studied as much as productivity or software costs (Kemerer 1995). Of the limited work done in examining quality, the focus has been on project-specific and team-specific factors such as personnel capability and project size (Krishnan et al. 2000). In other cases, the research has focused on the effects of project-level processes and process maturity on conformance quality (Harter et al. 2000). It is important to note that

although project- and team-specific factors have been studied, software quality is also determined by organizational factors (Rai et al. 1998). Organizations have an important role to play in instituting controls that ensure high quality software. It is not surprising that certain organizations have reputations for producing high quality software while others do not. The impact of organizational controls has not been studied in the context of quality and this research aims to address this gap in the literature. We believe that this study will make an important contribution to the software engineering and quality literature. In order to study the effects of organizational systems on software quality, we use organizational control theory as our theoretical lens.

Organizational control theory studies how control systems are designed in organizations to fit the tasks and objectives of the firm. A seminal paper in this area identifies three kinds of controls that organizations use to obtain favorable results (Ouchi 1979). Controls can be behavior-based, whereby certain kinds of behavior and processes are mandated by the organization. Alternatively, controls can be performance-based, whereby the employee is judged on the basis of performance. Third, control can be clan-based, which relies on social norms and shared values. Empirical work in this area has tested the presence of appropriate controls based on characteristics of the task and the organization (Eisenhardt 1985).

In the software domain, Kirsch (1996) studied the appropriate control mechanism to be used in managing software development and also included self-enforced control in her portfolio of control mechanisms. Most current work stops at identifying suitable control mechanisms for organizational activities based on task characteristics. There is little research that extends this reasoning into analyzing the effects of organizational control on performance. An example that illustrates the promise of applying control theory to software development settings can be found in Henderson and Lee (1992). The suitability of organizational controls can only be judged by improved organizational performance. Our proposed model aims to explain software quality contingent on the organizational controls used and thus extends the literature in organizational controls by studying the control–performance relationship.

A particularly relevant context for studying organizational controls and quality is the software industry in India, Ireland, and Israel (also known as the 3Is). The rise of the offshore software industry and the resulting disaggregation has created a need to study the antecedents of quality in this context. In addition, the software markets in these countries are thriving and their overall share of software in the global software market is increasing. For example, software exports from India in 2002 were $8 billion and are expected to reach $50 billion by 2008 (Kripalani 2002). The Irish software industry employs 25,000 people and generates software worth IR£6 billion (Crone 2002). The 3Is are among the largest software development industries outside North America (Amoribieta et al. 2001). Given the increasing importance of software quality and the size of the industry in these countries, it is important to study the controls exerted in software development organizations across these countries. The results from our research will help managers in these countries make more informed decisions on their organizational processes and the resulting impacts on software quality.

The research questions that we address in this paper are

1. What are the organizational control modes used in software development organizations in the 3Is?

2. How do organizational control modes impact the quality of software?

3. How is the relationship between organizational control modes and quality influenced by organizational and country-specific factors?

The proposed study will be conducted through a broad-based online survey aimed at software development organizations in the 3Is. The contributions of this work are in three areas. First, we extend the existing software engineering literature on quality drivers by studying the role of organizational controls. Second, we contribute to the literature in organizational control by examining the control modes to performance link. Third, we add to the extant literature on the offshore and international software industries by focusing on software development organizations in the 3Is. The next section describes the background theory in organizational controls and proposes the hypotheses that will be tested. The third section concludes the paper with a description of measures, methodology, and a work-plan for the research.

Theoretical Development

Control refers to the set of mechanisms designed to manage organizations and motivate individuals to work such that desired objectives are achieved (Kirsch 1996; Jaworksi 1988). Control theory draws upon organizational approaches to control based on cybernetic processes of monitoring and rewarding performance (Thompson 1967), supplemented by agency theory-based insights (Jensen and Meckling 1976) that also consider the role of uncertainty in determining appropriate control strategies.

Control theory posits that three main modes of control may be employed: behavior-based controls, outcome-based controls, and clan-based controls (Eisenhardt 1985). While the literature also points to self-control, allowing for individual discretion and intrinsic motivation, as providing a basis for managing organizations (Manz et al. 1987), we exclude it from the purview of this study due to our focus on organizational level controls.

In the use of behavior control, appropriate steps and procedures for task performance are laid out for the controlled entities and their performance is evaluated based on adherence to the prescribed procedures. The fundamental basis for operation of this control is supervision of subordinates by superiors to observe behaviors. In software development organizations, there is expected to be a diversion of preferences between software project participants and the firm's management with regard to the participants' effort. Also, in the absence of such controls, instrumental behaviors leading to desired outcomes may not be apparent to individual participants. Thus, an appropriate set of behavior controls is expected to lead to focused organizational efforts and thus enhance organizational outcomes. In the software development context, appropriate behavior controls can include development methodology specification (Alavi 1984; Necco et al. 1987), walk-throughs, and documentation-related behaviors (Kirsch 1997). Given that appropriate behavior controls are expected to motivate software project participants to work in accordance with organizational quality objectives, we propose that

> H1: Organizations that utilize higher levels of appropriate behavior controls will be associated with higher levels of software quality.

Organizations implementing outcome controls specify desired goals and employees are rewarded based on their meeting these goals. In software development organizations, outcome control can be exercised by setting goals for software defect rates, and software project participants can then be rewarded or sanctioned based on their individual or team's performance in meeting these goals. A cybernetic view of control suggests that individuals and teams would be motivated to take corrective action if they failed to meet quality goals (Jaworski 1988). We propose that

> H2: Organizations that utilize higher levels of appropriate outcome controls will be associated with higher levels of software quality.

Clan-based control modes operate through social norms and values such that the controlled entities internalize organizational goals and act in a manner consistent with the controlling entities expectations (Covaleski et al. 1998; Ouchi 1978). Clan-based control modes operate through interpersonal dynamics that socialize employees into conforming to an ideology that informally legitimizes certain behaviors while making others unacceptable. These controls require a high level of commitment on the part of each individual and a common agreement to socially prescribed behaviors. Clan controls may include a learning orientation and quality orientation. Research has associated organizations with a learning orientation to innovation in general (Hurley and Hult 1998), while quality orientation has been specifically associated with higher software quality (Ravichandran and Rai 2000). Given that the adoption of software process innovations is linked to higher quality (Kaplan et al. 1995), we expect organizations with innovation-oriented norms and values to have higher quality, as would organizations that have an overall quality orientation. Thus,

> H3: Organizations that have higher levels of appropriate clan controls will be associated with higher levels of software quality.

Agency theory suggests that if the behavior of the agent is unobserved by the principal, while behavior-based controls are used, there is a higher probability of shirking on part of the agent (Eisenhardt 1985). On the other hand, if behavior is observed, then the principal has complete information on the agent's actions and therefore can reduce shirking. Hence,

> H4: Behavior observability will positively moderate the relationship between behavior controls and software quality.

Knowledge of the transformation process refers to the managerial understanding of the means-ends relationships involved in the production activity. With this knowledge, the specification of rules of behavior would constitute an effective control mechanism because if the behaviors and processes conform to the managerial specifications, there is little uncertainty about the achievement of the output (Eisenhardt 1985). Hence,

> H5: Knowledge of the transformation process would positively moderate the relationship between behavior controls and software quality.

Outcome controls cannot be implemented effectively when the controller is unable to completely assess the achieved outcome (Kirsch 1996). Hence,

H6: Outcome measurability will positively moderate the relationship between outcome controls and software quality.

Application domain, requirements uncertainty, technology platform complexity, and organizational attrition rates are expected to impact software quality (Boehm 1981; Turner and Cochrane 1993; Williams 1999) and variance in these factors will be controlled for in our analysis. In addition, we expect differences across countries in terms of human capital and factor endowments, cultural conditions, and institutional forces that are also expected to lead to differences in quality (Amoribieta et al. 2001). To the extent that country cultures differ on dimensions such as uncertainty avoidance and individualism/collectivism (Hofstede 1991) companies in different countries would be expected to follow different patterns in their relative use of different modes of control.

The hypotheses and controls are captured in the model found in Figure 1.

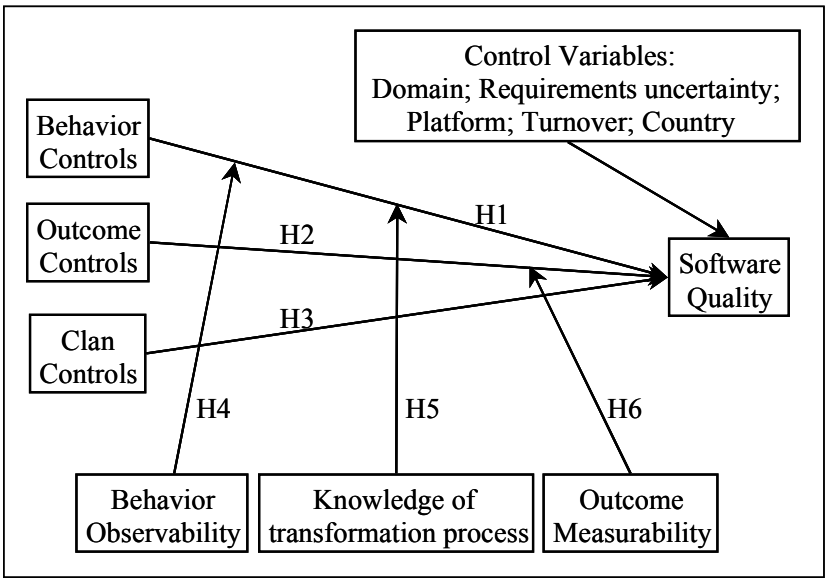

Figure 1. Managerial Control and Software Quality

Research Methodology

The study will utilize a cross-sectional survey data collection. The groundwork for the survey will also be laid down through visits to major software development centers in the 3Is in addition to liaising with software industry associations in each country. The survey is Internet-based and is currently undergoing pilot testing.

The model constructs (and respective indicators) have been adopted from previous research.

Research Plan

The survey has been implemented as a series of ASP-based Web pages. The survey is targeted at the quality assurance managers in software development organizations. Respondent organizations have been identified through interactions with umbrella organizations such as NASSCOM (National Association of Software and Services Companies) in India. The first round of data collection will occur during the fall and data analysis will be carried out later in the fall in preparation for presentation of preliminary results at the conference in December 2003.

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