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Gwanhoo Lee
University of Minnesota

Weidong Xia
University of Minnesota

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Gwanhoo Lee and Weidong Xia
Carlson School of Management
University of Minnesota
glee@csom.umn.edu wxia@umn.edu

Abstract

As both the business and technological environments change rapidly, information systems development (ISD) projects cannot succeed without being flexible and responsive to changes. However, there is little theoretical understanding of ISD project flexibility and its measurement. This research defines and conceptualizes the flexibility construct and develops a conceptual framework for measuring ISD project flexibility. The framework is based on two dimensions: measures of flexibility and types of ISD project flexibility. Measures of flexibility include time, cost, difficulty, amount and range. ISD project flexibility is classified into two types: flexibility to respond to end-user requirement changes and flexibility to respond to information technology (IT) changes. The significance and implications of the proposed framework for research are discussed.

Introduction

It has been well documented that a large proportion of information systems development (ISD) projects resulted in failure (The Standish Group 2001). Despite the considerable attention and efforts devoted to solving this problem for decades, ISD projects continue to fail to deliver effective information systems within project schedule and budget constraints. While many of long-standing risks for ISD projects still remain unresolved, new challenges are emerging (Schmidt et al. 2001). In particular, rapidly changing business and technological environments have made ISD projects even more difficult to succeed.

Due to relentless innovation, shorter product life cycles, and increasing globalization, today's business environments are characterized by such terms as hypercompetition and high-velocity. Since information systems are often intertwined with and embedded in business processes, an increasingly important challenge for ISD projects is how to rapidly respond to the changing end-user requirements. Information technologies (IT) also change rapidly; new technology is invented relentlessly, and current technology becomes easily obsolete. The average product life cycle of IT had declined from 53.6 to 30.8 months between 1988 and 1995 (Hamel and Prahalad 1994). ISD projects are required to adapt to new software development tools and infrastructure technology during the development process. A recent study confirms that IS practitioners perceive rapidly changing business and technological environments as emerging risk factors for software projects (Schmidt et al. 2001).

In order to succeed in the dynamic environments, ISD projects must be flexible and responsive to changes. Failing to respond to the changing environmental needs may result in irrelevant information systems that end-users do not accept. A recent issue of the *CIO magazine* shows that the need for flexibility is well recognized by the IS executives (Overby 2001). Although flexibility can be examined at different levels of analysis including individual, function, and firm, it is important to investigate flexibility at the IS project level because most IS development, implementation, and maintenance activities are organized in the form of projects. Since ISD project flexibility is an underdeveloped construct in the literature, it is important to develop conceptual foundations of the construct. The purpose of this research is two fold. First, we define and conceptualize the ISD project flexibility construct. We then propose a conceptual framework for measuring the construct.

Previous Literature

The flexibility construct has been conceptualized in many different contexts. In the strategic management literature, strategic flexibility is viewed as the capability to change a firm's strategy to respond to environmental changes in a timely and appropriate manner (Das and Elango 1995). Similarly, manufacturing flexibility is defined as a production system's capability of exhibiting

a wide range of states or behaviors to meet changing customer demands (Slack 1983). Adopting this conceptualization, IS researchers have defined IT infrastructure flexibility as the organizational capability to support a variety of information technologies and information services (Byrd and Turner 2000; Duncan 1995). Kanellis et al. (1998) defined flexibility of an information system as the ability to get information out of the system when the user wants, in the form that she or he wants it. When flexibility is conceptualized as organizational capability, the resource-based view of the firm can be a useful theoretical lens to examine the construct.

Very recently, the notion of dynamic capability has gained attention from management researchers. Dynamic capabilities are defined as the firm's abilities to integrate, build, and reconfigure internal and external resources, competences and capabilities to address rapidly changing environments (Eisenhardt and Martin 2000; Teece et al. 1997). This definition of dynamic capability is similar to that of flexibility. The difference between the two constructs is that dynamic capabilities appear to focus more on dynamic processes that create new organizational capabilities, whereas flexibility focuses more on organizational responses to environmental changes.

Researchers have consistently found that flexibility is a complex, multidimensional and hard-to-capture construct (Bahrami 1992; Sethi and Sethi 1990). As a result, many different dimensions and types of flexibilities have been proposed. For example, researchers have made distinctions between product and process flexibilities (Athey and Schmutzler 1995), between resource and coordination flexibilities (Sanchez 1995), between realized and potential flexibilities (Dixon 1992), between speed and variety flexibilities (Volberda 1996), to name a few.

Defining ISD Project Flexibility

The Merriam-Webster's Dictionary defines 'flexible' as (1) capable of being flexed, (2) yielding to influence, and (3) characterized by a ready capability to adapt to new, different, or changing requirements. Similar to the third definition in the dictionary, flexibility has been defined by most of the literatures, including information systems, strategic management, and operations management, as the *capability* to respond to environmental changes.

In order to understand how IS practitioners define flexibility in their own contexts, we interviewed twelve ISD project managers in a number of companies from various industries in the Midwest region. Interestingly, many of the managers could not clearly articulate the meaning of flexibility, which speaks to the ambiguity and complexity of the term in practice. Several managers, however, defined flexibility in ways that were consistent with prior literatures. For example, the managers defined flexibility as "ability to deal with new things coming up without incurring much costs," "being able to continue to evaluate what is going on and take reactions to changes," and "being able to effectively respond to any changes."

In this research, based on the prior literatures and our interviews with the ISD project managers, we define *ISD project flexibility* as the *ISD project's capability to effectively respond to project environmental changes in an efficient manner*. Before developing the framework for the measurement of ISD project flexibility, it is necessary to clarify three keywords in our definition of ISD project flexibility: ISD project, capability, and project environmental changes.

ISD Project. How ISD flexibility is defined and measured depends on the types of the projects. It is important to clearly define the types of projects that are considered in this research. In this research, IS development refers to the analysis, design, and implementation of business software applications, including major enhancement of existing systems and work on new systems yet to be installed (Swanson and Beath 1989). Examples of ISD projects include in-house system development and packaged software implementation. However, ISD projects in this research do not include minor enhancement or repair of operational systems.

Capability. According to the resource-based view of the firm literature, a capability refers to the capacity for a team of resources to perform some task or activity (Grant 1991). While resources are the source of a firm's capabilities, capabilities are the main source of its competitive advantage. Examples of capabilities include high-quality manufacturing, good supplier relationship, service excellence, innovation, and short product development cycles. Although most strategic management literature concerns firm-level capabilities, it appears that capabilities can be defined at different levels such as personnel and project. ISD project flexibility, therefore, can be viewed as the project-level capability that uses a team of project resources to meet the changing needs in the project environments.

Project Environmental Changes. Flexibility is necessitated by environmental changes. If the environment is perfectly stable, there is no need for flexibility. ISD projects are mostly dynamic. "We plan but always new issues come up," said one of the

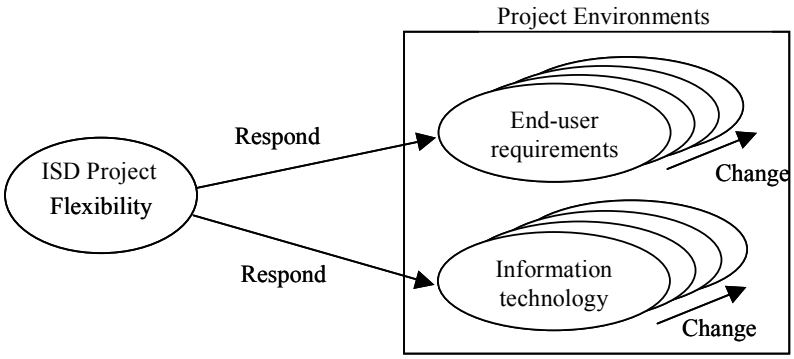

Figure 1. The Context of ISD Project Flexibility

managers in our interviews. Prior literature suggests that the typical ISD projects face significant environmental changes. Boehm (1991) proposed a list of top ten project risk items in which *continuing stream of requirements changes* ranked very high. In a recent study, Schmidt et al. (2001) reported a list of top software project risks including *unstable corporate environment*, *a climate of change in the business and organizational environment*, *changing scope/objectives*, *introduction of new technology*, and *stability of technical architecture*. In this research, we consider only the environmental changes that occur *during* the ISD projects. Environmental changes that occur *after* projects have been completed are not in the scope of this research. Specifically we propose two distinct types of project environmental changes: end-user requirement changes and information technology changes (Figure 1). Both end-user requirements and IT are changing over time and ISD projects need to respond to those changes to be successful.

A Conceptual Framework for Measuring ISD Project Flexibility

Since flexibility is multidimensional, most flexibility measures in the prior literature consist of more than one component or dimension. In consistency with the prior literature that treats flexibility as a construct with multiple dimensions, we propose that ISD project flexibility is a multidimensional construct that taps into more than one aspect of project capabilities. A conceptual framework for this complex construct must be first in place in order for a measurement to be systematically developed. The conceptual framework that we propose is based on two dimensions: *measures of flexibility* and *types of ISD project flexibility*. The first dimension specifies different ways of measuring the flexibility construct. The second dimension distinguishes different types of ISD project flexibility based on different types of project environmental changes.

Measures of ISD Project Flexibility

Flexibility can be measured in terms of various dimensions. Researchers have proposed various measures of flexibility. Table 1 shows some examples of flexibility measures. Integrating the past research, we propose seven measures of flexibility: *time*, *cost, effort, difficulty, amount, range, and impact*. Other measures such as *speed* and *variety* are significantly overlapped with these seven measures that we propose. *Time* and *cost* are the most widely used measures of flexibility in the prior literature. Effort refers to resources required to respond to changes. *Difficulty* captures the cognitive or organizational difficulties in responding to changes. *Amount* refers to the proportion of the total environmental changes that the project actually responded to. *Range* refers to the variety of environmental changes that the project responded to. *Impact* refers to performance that was affected by making changes. In sum, the first four measures (time, cost, effort and difficulty) capture the 'efficiency' aspects of ISD flexibility, whereas the last three measures (amount, range, and impact) capture the 'effectiveness' aspects of ISD flexibility.

Table 1. Measures of Flexibility

Source	Measures	Integrated measures
Das and Elango (1995)	speed, cost, amount	*Efficiency measures* - time - cost - effort - difficulty *Effectiveness measures* - amount - range - impact
Sanchez (1995)	time, cost, difficulty, range	
Nelson and Ghods (1998)	time, cost, effort, impact	
Young-Ybarra and Wiersema (1999)	ease	
Athey and Schmutzler (1995)	cost	
Slack (1983)	range	
Volberda (1996); Bahrami (1992)	speed, variety	

Types of ISD Project Flexibility

Because different project capabilities are required to respond to different types of project environmental changes, the definition and measurement of the ISD project flexibility construct depend on the types of environmental changes that the project must respond to. Considering the types of ISD project environmental changes makes the definition and measurement of ISD flexibility context-specific, and, therefore, may provide more meaningful results. Based on the conceptualization shown in Figure 1, we define two types of ISD flexibility: (1) flexibility to respond to end-user requirement changes and (2) flexibility to respond to IT changes. We propose that these two types of flexibility represent different project capabilities that are based on different sets of knowledge, skills, and processes.

Flexibility to respond to end-user requirement changes. In order to develop measurement of this type of flexibility, it is critical to identify relevant end-user requirements. As shown in Table 2, there exist several classifications of end-user requirements in the IS literature. Integrating these various classifications, for the purpose of this research, we propose a classification scheme for end-user requirements that is composed of *basic functional requirements* and *non-functional requirements*. Basic functional requirements include inputs, outputs, processes, stored data, and interface with other systems. Non-functional requirements include response time, reliability, security, and backup/recovery.

Table 2. Classifications of End-User Requirements

Capability Maturity Model	Jalote (2000)	Function Point Analysis	Whitten et al. (2001)
Technical requirements - Performance - Design constraints - Interface requirements - Programming language - End-user functions Non-technical requirements - Products to be delivered - Delivery dates - Milestones * Source: SEI (1994)	Business requirements - Objectives/scope Functional requirements - Business events - Inputs/outputs - Relationship between inputs and outputs - Precedence among events - Screens/reports External interface Operating environment - Hardware/software/network Performance requirements - Response time/throughput Standards requirements - Interface, coding, document Special user requirements - Safety, security, reliability	External inputs External outputs Logical internal files External interface files External inquiries * Source: Low and Jeffery (1990)	Functional requirements - Inputs - Outputs - Processes - Stored data Non-functional requirements - Throughput - Response time, etc.
Proposed classification scheme			
Basic functional requirements - Inputs - Outputs - Processes - Stored data - External interface		Non-functional requirements - Response time - Reliability - Security - Backup/recovery	

Flexibility to respond to IT changes. Typically, an ISD project deals with two types of information technologies: software development tools and infrastructure technologies. Software development tools include programming languages/environments, CASE (computer-aided software engineering) tools, and packaged software. These tools are selected for specific ISD projects based on user needs and technology capabilities. In contrast, infrastructure technology can be shared by multiple ISD projects. According to Duncan (1995), infrastructure technology includes platform technology (i.e., hardware and operating systems), network/telecommunication technologies, key enterprise data, and core enterprise applications. Since most ISD projects depend on the infrastructure technology components, changes in infrastructure technology components would significantly affect ISD project processes and outcomes. Therefore, in order to be successful, an ISD project must be flexible to respond to changing infrastructure technologies.

Proposed Conceptual Framework

By combining the two dimensions, we develop a conceptual framework for measuring ISD project flexibility (Figure 2). The framework consists of four cells, each of which reflects a conceptually distinct facet of ISD project flexibility. *Cell I* measures the efficiency aspect of the ISD project flexibility to respond to end-user requirement changes while *Cell II* captures the effectiveness aspect of the ISD project capability to respond to end-user requirement changes. Similarly, *Cell III* and *IV* measure the efficiency and effectiveness aspects of the ISD project flexibility to respond to IT changes, respectively. *Cell I* and *Cell II* measure flexibility with respect to end-user requirements changes while *Cell III* and *Cell IV* measure flexibility regarding IT changes. On the other hand, *Cell I* and *Cell III* tap into efficiency aspects of flexibility whereas *Cell II* and *Cell IV* focus on effectiveness aspects of the construct. We propose that each of these four cells independently contributes to the overall ISD project flexibility.

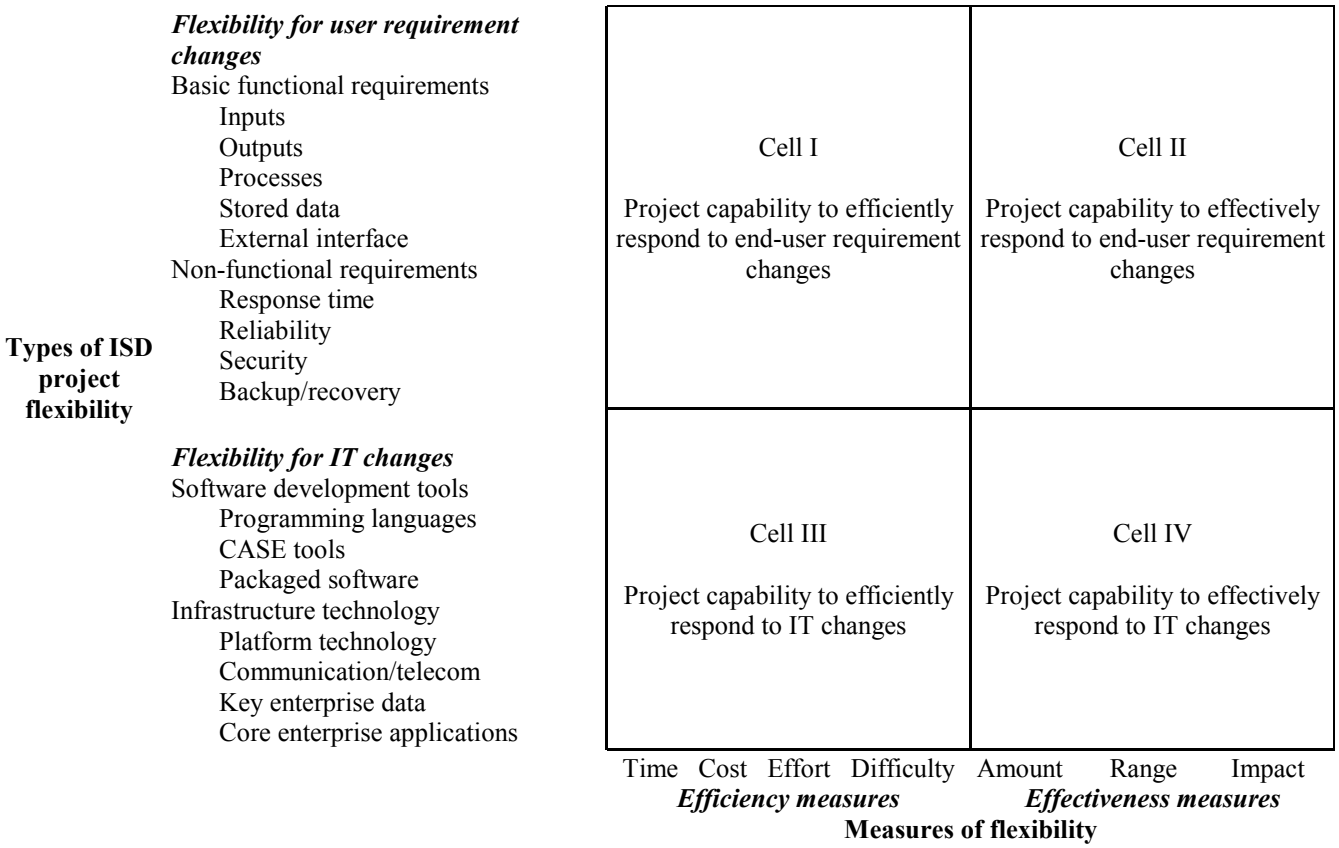

Figure 2. A Conceptual Framework for Measuring ISD Project Flexibility

Discussion and Conclusion

The proposed framework has several strengths. It reflects the multi-dimensional nature of the ISD project flexibility construct. In addition, the framework is specific to the context of ISD projects. This specificity can limit the generalizability of the framework to other contexts, but it enhances the utility of the framework for the ISD project management. We developed the framework strictly based on our definition and conceptualization of ISD project flexibility. As a result, the framework would allow us to develop the instrument that measures the actual flexibility construct rather than its antecedents. This will overcome the weaknesses of some existing flexibility measures that capture the antecedents of flexibility instead of flexibility itself. For example, if a measure assesses the extent of communications between the end-users and the IS staff, it is actually capturing an antecedent of flexibility instead of flexibility itself. We tried to avoid this problem in this research. Our framework focuses on the *realized flexibility* rather than the *potential flexibility*. That is, we are interested more in how ISD projects actually responded to changes than in how ISD project is potentially flexible with respect to future changes.

This framework can be used as the basis for developing an instrument to measure ISD project flexibility. The focus of our research in the next step is to design studies to develop and validate such an instrument. A two-stage approach can be used for developing and validating the measurement. In the first stage, an initial pool of items will be generated based on the literature and field interviews with ISD project managers using focused groups and Q-sort techniques. This initial pool will then be subject to an exploratory factor analysis using a large-scale survey of ISD project managers. The results of this stage will be an initial understanding of the factorial structure and psychometric properties of the measurement. In the second stage, the instrument resulted from the first exploratory stage will be subject to a confirmatory factor analysis using an separate large-scale survey of ISD project managers. The results of this stage will be an instrument with tested validity and reliability that can be used for developing research models that test theories related to ISD project flexibility. The instrument can also be used to generate guidelines that ISD project managers can use in their practice for designing and managing ISD project flexibility in order to effectively respond to business and technological changes.

Despite the strong needs for flexibility in ISD projects, virtually no prior research has been done to define and operationalize the ISD project flexibility construct. This research is the first attempt to conceptualize the ISD project flexibility construct and to propose a conceptual framework for developing measurement of the construct. Therefore, this research contributes to the literature by providing a foundation for future research in the area of ISD project flexibility. There are several areas for future research. Future research may extend the current conceptualization of ISD project flexibility to include not only flexibility during the project but also flexibility before or after the project. Furthermore, it would be interesting if ISD project measures incorporate the notion of system development life cycle that might affect flexibility. Finally, we call for future research that tests relationships between ISD project flexibility, its impact (e.g., project success), and its antecedents (e.g., team autonomy).

References

Athey, S. and Schmutzler, A. "Product and Process Flexibility in An Innovative Environment," *Rand Journal of Economics* (26:4), 1995, pp. 557-574.

Bahrami, H. "The Emerging Flexible Organization: Perspectives from Silicon Valley," *California Management Review*, Summer, 1992, pp. 33-52.

Boehm, B.W. "Software Risk Management: Principles and Practices," *IEEE Software*, January 1991, pp. 32-41.

Byrd, T.A. and Turner, D.E. "Measuring the Flexibility of Information Technology Infrastructure: Exploratory Analysis of a Construct," *Journal of Management Information Systems* (17:1), 2000, pp. 167-208.

Das, R.K. and Elango, B. "Managing Strategic Flexibility: Key to Effective Performance," *Journal of General Management* (20:3), 1995, pp. 60-75.

Dixon, J.R. "Measuring Manufacturing Flexibility: An Empirical Investigation," *European Journal of Operational Research* (60), 1992, pp. 131-143.

Duncan, N.B. "Capturing Flexibility of Information Technology Infrastructure: A Study of Resource Characteristics and Their Measure," *Journal of Management Information Systems* (12:2), 1995, pp. 37-57.

Eisenhardt, K.M. and Martin, J.A. "Dynamic Capabilities: What Are They?" *Strategic Management Journal* (21), 2000, pp. 1105-1121.

Grant, R.M. "The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation," *California Management Review*, Spring, 1991, pp. 114-135.

Hamel, G. and Prahalad, C.K. *Competing For the Future*, Boston, MA: Harvard Business School Press, 1994.

Jalote, P. *CMM in Practice: Processes for Executing Software Projects at Infosys*, Boston, MA: Addison-Wesley, 2000.

Kanellis, P., Lycett, M. and Paul, R.J. "An Interpretive Approach to the Measurement of Information Systems Success: From Concept to Practical Application," In *Information Systems Success Measurement*, E. J. Garrity and G. L. Sanders (Ed.), Hersey, PA: Idea Group Publishing, 1998.

Low, G.C. and Jeffery, D.R. "Function Points in the Estimation and Evaluation of the Software Process," *IEEE Transactions on Software Engineering* (16:1), 1990, pp. 64-71.

Nelson, K.M. and Ghods, M. "Measuring Technology Flexibility," *European Journal of Information Systems* (7), 1998, pp. 232-240.

Overby, S. "Quick Change Artists," *CIO*, August 15, 2001, pp. 90-98.

Sanchez, R. "Strategic Flexibility in Product Competition," *Strategic Management Journal* (16), 1995, pp. 135-159.

Schmidt, R., Lyytinen, K., Keil, M. and Cule, P. "Identifying Software Project Risks: An International Delphi Study," *Journal of Management Information Systems* (17:4), 2001, pp. 5-36.

SEI. *The Capability Maturity Model: Guidelines for Improving the Software Process*, Boston, MA: Addison Wesley, 1994.

Sethi, A.K. and Sethi, S.P. "Flexibility in Manufacturing: A Survey," *The International Journal of Flexible Manufacturing Systems* (2), 1990, pp. 289-328.

Slack, N. "Flexibility as a Manufacturing Objective," *International Journal of Operations & Production Management* (3:3), 1983, pp. 4-13.

Swanson, E.B. and Beath, C.M. "Reconstructing the Systems Development Organization," *MIS Quarterly* (13:3), 1989, pp. 293-307.

Teece, D.J., Pisano, G. and Shuen, A. "Dynamic Capabilities and Strategic Management," *Strategic Management Journal* (18:7), 1997, pp. 509-533.

The Standish Group. "The Chaos Report," 2001.

Volberda, H.W. "Toward the Flexible Form: How to Remain Vital in Hypercompetitive Environments," *Organization Science* (7:4), 1996, pp. 359-372.

Whitten, J.L., Bentley, L.D. and Dittman, K.C. *System Analysis and Design Methods*, Columbus, OH: The McGraw-Hill Companies, 2001.

Young-Ybarra, C. and Wiersema, M. "Strategic Flexibility in Information Technology Alliances: The Influence of Transaction Cost Economics and Social Exchange Theory," *Organization Science* (10:4), 1999, pp. 439-459.