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UNDERSTANDING THE FLEXIBILITY GAP OF INFORMATION SYSTEMS DEVELOPMENT: AN EMPIRICAL STUDY

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ABSTRACT

Information systems development projects (ISDP) are difficult to manage partly because both business and technology change frequently during the projects. This article reports the findings of an empirical study that investigates the pattern of changes occurring during a project, the pattern of the project team responses, the impacts of ISDP team flexibility on project performance, and project factors that distinguish more flexible teams from less flexible teams. The results reveal that business changes are more prevalent than technology changes during ISDPs and that there are significant gaps between the change patterns and the response patterns. We found that project teams are less effective in handling business changes than technology changes, which causes, what we call, the ISDP flexibility gap. Higher ISDP team flexibility is found to be associated with better project performance. The results also suggest that managers can improve their ISDP team flexibility and bridge the flexibility gap by keeping project size small, providing the project team with more autonomy, increasing member heterogeneity, and securing resource slacks. This study provides empirical evidence that support some of the principles and practices recommended by agile development. We discuss the implications of the findings for information systems development theory and practice.

Keywords: Information system development, business change, technology change, flexibility, responsiveness, project performance, team autonomy, team heterogeneity, resource slack.

INTRODUCTION

Information systems development projects (ISDPs) are inherently challenging because they must simultaneously deal with both business requirements and information technology (IT) tools and infrastructure. The Standish Group International's Chaos Reports have illustrated that organizations have continuously suffered from low ISDP success rates over the last two decades. The Standish Group's 1994 report [15] showed that US com-

panies spent more than \$250 billion each year in the early 1990s on ISDPs, with only 16.2 percent considered successful. The Group's 2004 report [16] found that, although US companies invested significantly more money annually in the 2000s for IS development than they did in the 1990s, 53% of all ISDPs were late and/or over budget and an additional 18% either failed outright or were cancelled prior to completion. The results suggest that, with only a marginally improved success rate, more resources

are being spent on ISDPs that are not satisfactorily meeting project goals and organizational needs.

One explanation for the high failure rate is that the rapidly changing business and technology environments have made ISDPs increasingly uncertain and complex [4, 7, 9]. Due to relentless innovation, shorter product life cycles and increasing globalization, business environments are changing frequently. Since information systems (IS) are often intertwined with and co-evolving with business processes, an increasingly important challenge for ISDPs is how to effectively respond to changing business requirements. "By the time you design, program, and implement the [information systems] solution, the world has changed anyway," says an IS executive in the airlines industry who participated in our study.

IT, at the same time, has also been changing rapidly. For instance, computing paradigms have shifted from mainframe, to client-server, to web-based computing, and to mobile computing over a relatively short period of time. As predicted by the "Moore's Law", IT indeed has gone through rapid innovation cycles. "You may have a technology that seemed like the right choice at the time, but is obsolete when you put it in," says an IS manager who participated in our study. During its development lifecycle, an ISDP often has to adopt emergent software development tools and adapt to new IT infrastructure. Rapid IT changes challenge those responsible for software development and often cause problems in such areas as software quality and application integration.

Business and technology changes occur often during projects and that ISDP team flexibility is a critical success factor for complex, volatile projects [3, 4, 7, 9, 12]. In this study, we define ISDP team flexibility as the extent to which the project team is able to respond to business and technology changes with little additional cost, time, and effort [13]. Recognizing that the lack of ISDP team flexibility and responsiveness might be a key factor for software development failure, practitioners proposed agile software development approaches such as XP (Extreme Programming), Scrum, ASD (Adaptive Software Development), Crystal, and FDD (Feature Driven Development) as practical solutions to improve software development flexibility to respond to changing requirements [1, 5, 9, 12]. There is a common set of values and principles underlying the various specific agile methods and tools, such as sense and response, short iterative lifecycles, self-organizing teams, and continuous discovery and learning [1, 5]. While an increasing number of organizations have embraced agile approaches [4, 17], most of the literature has been based on anecdotal observations [4, 6, 8, 10, 14]. In particular, there is a lack of empirical studies that systematically examine the types and patterns of changes, the

types and patterns of responses by ISDP teams, impacts of ISDP team flexibility on project performance, and project factors that affect ISDP team flexibility.

While changes invariably occur during projects, IS organizations generally demonstrate difficulties in coping with them [2, 5]. In a 2006 survey, Koch [11] reported that only 11 percent of IS organizations were able to keep up with business demands and that 76 percent of IS organizations were not able to effectively cope with changing business needs. In order for organizations to develop processes and mechanisms to effectively cope with changes, they must understand not only the characteristics of the changes but also their ISDP teams' ability to respond to those changes. In addition, to improve ISDP team flexibility, organizations must be aware of the key project factors that affect software development flexibility. Such understandings will help managers attend to the most critical changes, allocate resources to areas where flexibility is most needed, and improve flexibility by controlling important project factors. In this article, we report the findings of an empirical study that aims at addressing the following questions:

- Q1) How frequently do major types of changes occur during ISDPs? What are the patterns of these changes?*
- Q2) How flexible are ISDP teams in responding to major types of changes? What are the patterns of ISDP team responses to those changes?*
- Q3) Are there any gaps between the change patterns and the response patterns?*
- Q4) What are the main impacts of ISDP team flexibility on project performance?*
- Q5) What are the key project factors that distinguish more flexible teams from less flexible teams?*

RESEARCH METHODS

We conducted this study using a research process involving multiple data sources and methods. First, the research questions were identified and formulated through extensive discussions with a number of IS executives and managers. Second, we identified 15 types of business and technology changes through an iterative process including field interviews with 12 ISDP managers, focus group discussions with 45 IS managers, and two pilot tests with 22 IS researchers and practitioners. Third, we collected large-scale data through an on-line survey of ISDP managers.

The respondents of our online survey were the members of the Information Systems Specific Interest Group (ISSIG) of the Project Management Institute. The size of the target respondent group was 1,740. In total, we obtained 565 responses, 505 of which were valid responses that were used for this research, resulting in a final response rate of 29%. The sample represented various industries, including consulting (5.8%), finance and insurance (20.1%), government (8.7%), healthcare (5.8%), manufacturing (13.9%), retail (5.1%), software (10.1%), telecommunications and network (5.4%), transportation (4.0%), utility (7.6%) and other (13.5%). Annual sales of the companies in the study sample ranged from less than \$100 million (26.2%), \$100 million to \$1 billion (31.1%), to over \$1 billion (42.7%). Size of the companies measured by number of employees ranged from less than 1000 (26.8%), 1000 to 10000 (40.6%), to over 10000 (32.6%). In the survey, the respondent was asked to identify a recently completed ISDP and provide assessments regarding types and extent of changes occurred during the project, the project team's responses, project performance, and factors that affect the project team's ability to respond to changes. Sizes of the projects in the study sample as measured by number of project team members ranged from less than 10 (24.7%), 10 to 50 (55.7%), to over 50 (19.6%). Project budgets ranged from less than \$100K (17.8%), \$100K to \$1 million (40.9%), to over \$1 million (41.3%). Project durations range from less than 6 months (24.5%), 6 to 12 months (40.5%), to over 12 months (35%).

RESULTS

Major Types of Changes

Changes occurring during an ISDP can be classified into two categories: (1) changes related to the business requirements of the project and (2) changes related to the technology environment of the project. Based on the literature, our field interviews and focus group discussions with ISDP managers, we identified nine major types of business changes and six major types of technology changes that occur most frequently and widely during ISDPs. The nine types of business changes are related to system objectives, system scope, system delivery date, project budget, system input data, system output data, business processes, data model/structure, and user requirements regarding interfaces. The six types of technology changes are related to software programming languages/tools, systems analysis and design methods, technology architecture, technology infrastructure (e.g., tele-

communications and networks), other systems that will be integrated with the application system under development, and enterprise master data.

Frequency and Pattern of Changes

Table 1 shows how commonly each type of the business and technology changes was observed in our study sample. The results indicate that all types of business changes, except for project budget, were ranked higher than all technology changes. Business changes tended to be observed in a majority of ISDPs, ranging from 80.8% to 91.9% of the ISDPs. On the other hand, technology changes tended to occur less often, albeit still a majority, ranging from 66.7% to 84.8%. On average, a specific type of business change was observed in 86.8% of the ISDPs whereas a specific type of technology change was observed in 77.9% of the ISDPs. The difference was statistically significant, indicating that business changes generally were observed significantly more frequently than technology changes in our study sample.

Within the category of business changes, system scope changes were the most commonly observed changes (in 91.9% of ISDPs), followed by changes in business rules/processes (88.9%), user interfaces (88.5%), system output data (88.1%), and system objectives (87.3%). Changes in project budget, although they were ranked relatively lower than the other business changes, were observed in 80.8% of ISDPs.

Within the category of technology changes, the most commonly observed changes were related to changes in the other systems that will be integrated with the application system under development (occurred in 84.8% of ISDPs), followed by changes in IT architecture (82.2%), changes in IT infrastructure (82.0%) and changes in systems analysis and design methods (77%). Changes in software programming languages occurred least commonly (66.7%).

Further data analyses revealed that about 64% of the ISDPs in our study sample experienced all nine types of business changes and that 98% of the ISDPs experienced at least one type of business change. About 58% of the ISDPs experienced all six types of technology changes and about 94% of the ISDPs faced at least one type of technology change. These results suggest that both business and technology changes were prevalent in the contemporary ISDPs.

Table 1: Frequency of Changes During ISDPs

Frequency Ranking	Specific change types	Change category	Frequency of changes (% of projects)
1	System scope	Business	91.9
2	Business rules/processes	Business	88.9
3	User interface	Business	88.5
4	System output data	Business	88.1
5	System objectives	Business	87.3
6	System delivery date	Business	85.9
7	System input data	Business	85.1
8	Data model/structure	Business	85.0
9	Other systems to be interfaced with	Technology	84.8
10	IT architecture	Technology	82.2
11	Project budget	Business	80.8
12	Analysis and design methods	Technology	77.0
13	Enterprise master data	Technology	76.8
14	IT infrastructure (network/telecom)	Technology	75.6
15	Programming languages	Technology	66.7

Degree and Pattern of Team Responses

Table 2 shows ISDP team responses to the aforementioned business and technology changes. Flexibility score indicates how efficiently an ISDP team responds to a given type of change in terms of time, cost, and effort. It was measured by a 7-point Likert-type scale in which higher numbers indicate greater responsiveness and flexibility of the ISDP team to a given type of change. The flexibility scores of the 505 ISDPs in our study sample ranged from 3.75 to 5.15. Whereas the flexibility scores for business changes ranged from 3.75 to 4.60, the flexibility scores for technology changes ranged from 4.36

to 5.15. This difference was statistically significantly ($t = 12.17, p < .01$).

Within the category of business changes, ISDP teams were most flexible in responding to changes in data model/structure but were least flexible in responding to changes in system delivery date. Within the category of technology changes, ISDP teams were most flexible in responding to changes in software programming tools, followed by changes in systems analysis and design methods and changes in IT infrastructure. ISDP teams were least flexible in dealing with changes in other interface systems.

Table 2: Flexibility Scores of ISDP Team Responses

Flexibility Ranking	Specific change types	Change category	Flexibility scores ¹
1	Programming languages	Technology	5.15
2	Analysis and design methods	Technology	4.94
3	IT infrastructure (network/telecom)	Technology	4.83
4	IT architecture	Technology	4.82
5	Enterprise master data system	Technology	4.78
6	Data model/structure	Business	4.60
7	System input data	Business	4.42
8	Other systems to be interfaced with	Technology	4.36
9	User interface	Business	4.31
10	Project budget	Business	4.27
11	System output data	Business	4.26
12	System objectives	Business	4.19
13	System scope	Business	3.97
14	Business rules/processes	Business	3.93
15	System delivery date	Business	3.75

Note: ¹Scores are based on 7 point scales (1 = lowest, 7 = highest)

Gaps between Change Patterns and Responses Patterns

A comparison between the patterns of the business and technology changes (Table 1) and the patterns of the ISDP team responses (Table 2) uncovers an intriguing relationship. As shown in Figure 1, the frequency rankings of business and technology changes were largely reversed with the flexibility rankings of team responses. These two rankings were significantly and negatively correlated (Spearman rank-order correlation coefficient (r_s) = - 0.83, $p < 0.01$). While business changes generally occurred more frequently than technology changes, ISDP teams tended to be less flexible in responding to business changes than to technology changes. For example,

changes in system scope, business rules/processes, user interfaces, system output data, system objectives, and system delivery date were placed in the upper half of the frequency rankings. However, the flexibility rankings for these changes fell in the lower half. In contrast, changes in IT architecture, IT infrastructure, analysis and design methods, enterprise master data, and software programming languages were placed in the lower half of the frequency rankings. However, the flexibility rankings for these changes fell in the upper half. The results suggest that there exist considerable gaps between change patterns and the patterns of the ISDP team responses, which we call the ISPD flexibility gap. Specifically, ISDP teams demonstrated less flexibility in dealing with business changes than with technology changes.

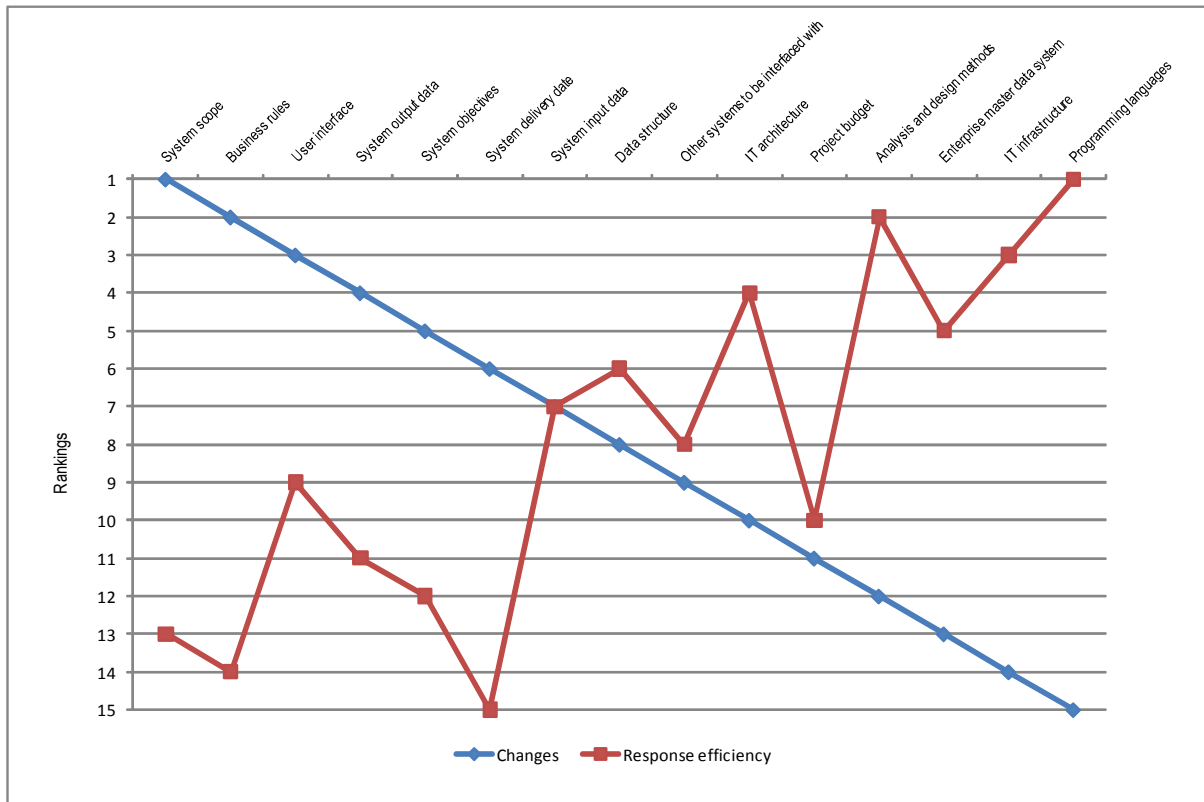


Figure 1: A Reversed Relationship Between Change Frequency and Team Flexibility

Impacts of ISDP Team Flexibility on Project Performance

In this study, project performance was assessed by four commonly used measures: on-time completion, within-budget completion, system functionality, and user satisfaction. Table 3 presents the correlations between ISDP team flexibility and the four indicators of project performance. The results suggest that, at the aggregate level, an ISDP team’s flexibility in dealing with both business and technology changes was positively and significantly associated with project performance. In general, the ISDP team flexibility to business changes was more significantly related to better project performance than its flexibility to technology changes.

As for each specific type of business changes, ISDP team flexibility in dealing with changes in system scope, system objectives, system delivery date, project budget, and user interface was associated with better project performance on all four performance indicators. ISDP team flexibility in responding to changes in business

rules/processes was positively related to project on-time completion, within-budget completion, and system functionality. On the other hand, ISDP team flexibility in responding to changes in system input data, system output data, and data structure, was positively associated with improved project performance in terms of on-time completion and within-budget completion.

As for each specific type of technology changes, ISDP team flexibility in responding to changes in programming languages and in systems analysis and design methods was positively associated with all four project performance indicators. ISDP team flexibility in dealing with changes in IT architecture and infrastructure (network/telecom) was positively associated with on-time completion, within-budget completion, and system functionality. ISDP team flexibility in responding to changes in other systems that the application under development will interface with was positively associated with on-time completion and system functionality. ISDP team flexibility in dealing with changes in enterprise master data system setups related positively to on-time completion and within-budget completion.

Table 3: Correlations Between ISDP Team Flexibility and Project Performance

ISDP team flexibility in responding to changes in		Project performance			
		On-time completion	Within-budget completion	System functionality	User satisfaction
Aggregate Level					
Business requirements		0.27**	0.29**	0.17**	0.15**
IT		0.16**	0.16**	0.17**	0.12**
Specific changes	Category of changes				
System objectives	Business	0.27**	0.25**	0.21**	0.20**
System scope	Business	0.29**	0.27**	0.23**	0.19**
System delivery date	Business	0.25**	0.27**	0.14**	0.13**
Project budget	Business	0.19**	0.36**	0.17**	0.17**
System input data	Business	0.22**	0.19**	0.07	0.05
System output data	Business	0.16**	0.17**	0.07	0.09
Business rules	Business	0.23**	0.22**	0.10*	0.09
Data structure	Business	0.16**	0.16**	0.08	0.02
User interfaces	Business	0.10*	0.15**	0.14**	0.13**
Programming languages	Technology	0.21**	0.21**	0.22**	0.15**
Analysis and design methods	Technology	0.13*	0.18**	0.25**	0.17**
IT architecture	Technology	0.17**	0.21**	0.15**	0.09
IT Infrastructure	Technology	0.14**	0.13*	0.12*	0.06
Other systems to be interfaced with	Technology	0.16**	0.09	0.11*	0.06
Enterprise master data	Technology	0.16**	0.14**	0.10	0.03

Note: ** Significant at the 0.01 level, * Significant at the 0.05 level

Overall, an ISDP's on-time and within-budget completion performance were positively impacted by ISDP team flexibility in responding to all types of changes. In contrast, project performance in terms of system functionality was positively influenced by ISDP team flexibility in responding to all business requirement changes except for those in system input data, system output data, and data structure and all technology changes except for those in enterprise master data. Similarly, user satisfaction was positively influenced by ISDP team flexibility in responding to business requirement changes in system objectives, system scope, system delivery date, project budget and user interface. With regard to technology changes, user satisfaction was positively affected by ISDP team flexibility in responding to changes in systems analysis and design methods and in program languages.

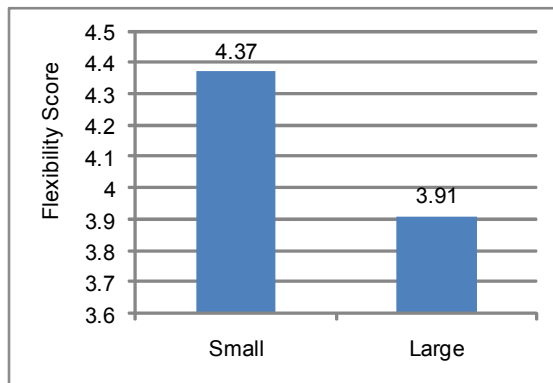
Project Factors Affecting ISDP Team Flexibility

Our study shows that the flexibility gap stems mainly from a lack of ISDP team ability to effectively deal with business changes. Therefore, the most important areas on which organizations need to improve are related to the flexibility to business changes. In order for organizations to develop meaningful mechanisms to increase ISDP team flexibility to business changes, they need to be aware of the key project factors that influence flexibility so that they can control those factors accordingly. In this study, based on the literature, field interviews and focus group discussions with ISDP managers, we identified four critical project factors: project size, team autonomy, team heterogeneity, and project resource slack. While there

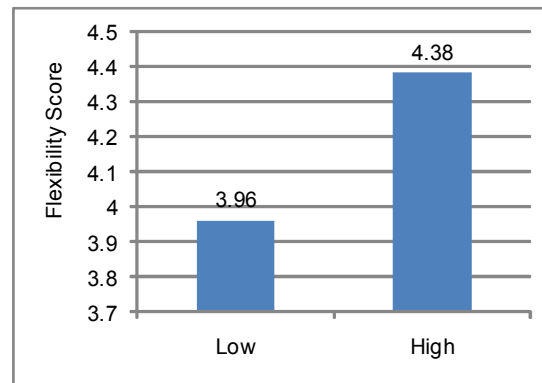
might be a number of other organizational and technical factors affecting flexibility, these four project factors represent important decision variables that managers can control to set up and manage the project. Using mean scores, we divided the ISDPs in our study sample into a high-level group and a low-level group for each factor. We then tested whether the high-level and the low-level groups are different in terms of their flexibility in responding to business changes.

Project size is one of the important factors affecting the structure and process of a project. We performed a t-test to compare the effect of project size on ISDP team flexibility to business changes. As shown in Figure 2(a), smaller projects demonstrated a significantly higher level of flexibility than larger projects ($t = 2.33, p = 0.02$). Project team autonomy refers to the extent to which a project

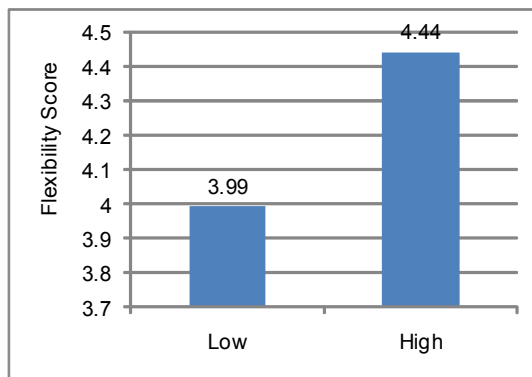
team has full power to make project-related decisions. Our t-test result indicates that project teams with higher levels of autonomy have greater flexibility than those with lower levels of autonomy ($t = 2.36, p = 0.02$). Project team heterogeneity refers to the extent to which the project team members are diversified in terms of skill, expertise, and experience. Our result indicates that project teams with greater member diversity have higher flexibility to business changes than those with less diversity ($t = 2.60, p = 0.01$). Project resource slack refers to the extent to which the project team is provided with options or backups for critical resources such as key personnel, project budget, schedule and technologies. Our result indicates that projects with greater resource slack have higher flexibility in dealing with business changes than those with less slack.



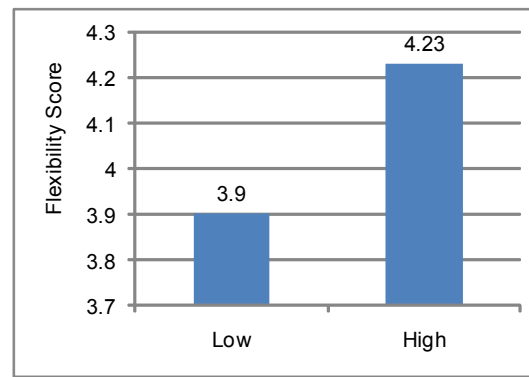
(a) Project size*



(b) Project team autonomy*



(c) Project team heterogeneity*



(d) Project resource slack**

Note: * The mean difference is significant ($p < .05$), ** The mean difference is marginally significant ($p < .1$)

Figure 2: Project Factors Affecting ISDP Team Flexibility

DISCUSSION

This study attempts to provide insights about (1) the types and patterns of changes occurring during ISDPs; (2) the patterns of ISDP team responses to those changes; (3) the gaps between the change patterns and the response patterns; (4) the effect of ISDP team flexibility on project performance; and (5) project factors that discriminate flexible ISDP teams from rigid teams.

The current study shows that both business changes and technology changes occur in nearly all ISDPs in the study sample and that most ISDPs experience all types of business and technology changes. Business changes are found to be more prevalent than technology changes. Importantly, we found that changes in relatively unstructured, uncontrollable, or enterprise-wide elements tended to be more prevalent than changes in relatively structured, controllable, or locally-contained elements. For example, within business changes, changes in system scope and business processes were more prevalent than changes in data structure and system input data, and, similarly, within technology changes, changes in architecture and other interface systems were more prevalent than changes in programming languages. These findings suggest that changes are everywhere and managing changes is an important integral part of ISDP management. To be effective in monitoring and managing changes, ISDP teams must pay closer attention to business changes and the changes that are relatively unstructured, uncontrollable, or enterprise-wide.

While business changes were more prevalent than technology changes, ISDP teams were found to be less flexible to business changes. We refer to this problem as the ISDP flexibility gap. We argue that this problem is largely caused by the aforementioned change patterns and the inherent limitations of ISDP team capabilities. That is to say, while unstructured, uncontrollable, or enterprise-wide changes are more prevalent, ISDP teams tend to be more capable of responding to changes that are well-defined, locally-contained, and under their control. Business changes are usually outside of the ISDP team's immediate control, thus making it difficult for teams to effectively deal with. Furthermore, our field interviews and focus group discussions confirm that ISDP teams tend to be more technology-oriented than business-oriented in terms of their skills, experiences, and capabilities. ISDP teams are dominated by "technical" experts, with few business domain experts. This unbalance in skills and expertise makes it difficult for ISDP teams to accurately understand and quickly respond to business changes.

This study found that ISDP team flexibility positively affects project performance in general. However, a

few specific findings seem to warrant further discussions. We found that ISDP team flexibility to data-related changes (e.g., changes in system input data, system output data, data structure, and enterprise master data) did not significantly affect system functionality. A plausible explanation for this finding is that data-related changes might have indirect rather than direct effects on system functionality by causing other changes such as scope changes. User satisfaction was found to be largely affected by ISDP team flexibility to business changes in system objectives, system scope, system delivery date, project budget and user interface but not by flexibility to data-related business changes. A plausible interpretation is that user satisfaction is likely to be more sensitive to meeting overall project goals for scope/time/cost than to detailed specifications and functionalities of the system. On the other hand, user satisfaction was positively affected by ISDP team flexibility to technology changes in systems analysis and design methods and program languages but not by flexibility to other technology changes such as IT architecture. One interpretation of this finding is that, changes in systems analysis and design and program languages tend to directly affect the system outcome, whereas changes in IT architecture and infrastructure are invisible and indirectly affect specific systems.

Our study results suggest that project size, team autonomy, team heterogeneity and project resource slack affect ISDP team flexibility especially to business changes. Smaller projects, increased team autonomy, increased team heterogeneity, and increased project resource slack demonstrated greater team flexibility. Compared to smaller projects, larger projects tend to be more formalized and more complex, requiring higher levels of coordination. As a result, they are slower and costly in sensing and responding to environmental changes. Increased team autonomy enables the project team to sense and respond to business changes quickly through fast, informed decisions made by team members. Project team members' experience and expertise in various business functions/processes would help them effectively communicate with business users, interpret and understand business changes, and implement solutions while minimizing user resistance. Resource slack serves as a "buffer" for dealing with unanticipated business changes, thus providing resource flexibility for ISDP teams. Therefore, as the rate of business changes increases, organizations should consider decomposing large projects into smaller projects whenever possible, promoting decentralized decision making, increasing the diversity in ISDP team members' expertise and skills, and reserving appropriate levels of resource slacks. Reserving a large amount of project resource slack can be challenging because ISDP teams are

under pressure for “doing more with less.” Nevertheless, ISDP teams need to secure some resource slacks in order to be able to address unanticipated demands and requirements.

The findings of this study provide empirical evidence that support some of the key principles and practices recommended by agile development. For example, most agile methods advocate small project teams. Our finding that smaller projects were more efficient in dealing with changes provides an empirical support for the recent software development methodologies and approaches that stress short lifecycle and fast delivery. Compared to large projects, small projects are easier to define requirements and require less communications and coordination when changes occur. In many organizations, software development projects were required to deliver measurable, tangible results within three to six months. When a project is too large to be completed in three to six months, the project needs to be divided into several phases or time-boxes, with well-defined deliverables for each phase or time-box. In addition, agile development views team autonomy and team diversity as important principles and practices that foster software development flexibility [12]. For example, agile development advocates self-organizing, self-directed, and self-disciplined teams [9, 12]. Furthermore, agile development posits that a software team should have a variety of skills and perspectives that are necessary for sensing problems and pitfalls, thinking of multiple ways to solve problems, and implementing the solutions [1]. To our knowledge, no research has empirically validated these basis agile principles and practices.

CONCLUSION

In conclusion, business changes occur more frequently than technology changes in contemporary ISDPs. However, ISDP teams are less flexible in responding to business changes than technology changes, thus creating the problem of the ISDP flexibility gap. Since flexibility has significant effects on ISDP performance, ISDP teams should seek to improve their flexibility, especially to business changes. ISDP teams can build flexibility by keeping team size small, staffing teams with diverse skills and experiences, allowing for decision autonomy, and securing resource slacks. With ever-increasing change rates, ISDP teams need to be able to continuously monitor important changes and strategically build and maintain team flexibility in order to succeed in the undertakings of complex and uncertain software development tasks.

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