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The Nature Of Complexity In Is Projects And Programmes

Robert W. Gregory
University of Göttingen, Göttingen, Germany, RWGregory@iese.edu

Everlin Piccinini
University of Göttingen, Göttingen, Germany, everlin.piccinini@stud.uni-goettingen.de

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Piccinini, Everlin, University of Göttingen, Platz der Göttinger Sieben 5, 37073 Göttingen, Germany, everlin.piccinini@wiwi.uni-goettingen.de

Gregory, Robert, University of Göttingen, Platz der Göttinger Sieben 5, 37073 Göttingen, Germany, robert.gregory@wiwi.uni-goettingen.de

Abstract

It is frequently mentioned in the literature that Information Systems (IS) projects and programmes fail because of the involved complexity. However, we have a lack of understanding about the components of complexity and the specific constituting constructs (e.g., variety). This paper addresses this theoretical gap through a systematic literature review of IS project management literature based upon the application of Xia and Lee (2005)'s framework of IS project complexity. We contribute to this framework in multiple ways. First, we provide a state-of-the-art review of literature that builds upon Xia and Lee (2005)'s study and do not only find support for the previously identified components of complexity, but also identify multiple other relevant components to be potentially considered in future empirical studies. Second, we contribute to the framework by examining the differences between IS projects and programmes in terms of the relevance of individual complexity components. Finally, an important conceptual contribution of this paper is to aggregate the various identified complexity components into four distinct constructs of complexity, i.e., variety, interdependency, uncertainty, and ambiguity. Our extended conceptualization of IS project and programme complexity provides a useful guide for future empirical research, which is needed to understand why IS projects and programmes fail.

Keywords: complexity, information systems projects, information systems programmes, literature review, variety, interdependency, uncertainty, ambiguity

1 Introduction

Managing information systems (IS) projects is extremely challenging, particularly when they are run in the context of a strategic programme, which consists of multiple, interrelated projects (Pellegrinelli et al. 2007). It is known that IS projects are prone to failure; previous research shows that they operate on average 45 percent over budget, 7 percent over time, and deliver 56 percent less value than estimated (Bloch et al. 2012). One of the reasons IS projects fail is because they are usually very complex (Murray, 2000). Complexity is a phenomenon that arises from a number of varied interrelated elements and their emergent unpredictable behaviour (Isik, 2010). Xia and Lee (2005) state that coordination and control is needed to cope with complexity in IS projects, which results from both technological and organizational factors. However, managing multiple interconnected IS projects in combination in the context of an IS programme involves an even greater degree of coordination and control in order to meet the strategic program goals, making IS programmes even more challenging than IS projects. One of the pertinent issues is coping with the complexity that results, for example, from multiple interdependencies between projects. To date, both in theory and practice we have a lack of understanding about the components of IS project complexity. This is an important theoretical gap that we address with this paper. While in the context of IS projects there has been some research (e.g., Xia and Lee 2005), we are not aware of any study that has examined complexity in IS projects *and* programmes, and compared the two.

The term IS project complexity is often used in IS literature without drawing upon an accurate definition. Xia and Lee were among the first to develop a conceptualization and measurement of IS project complexity, which they defined broadly as being composed of multiple organizational and technological aspects that are interrelated and subject to changes over time (Xia and Lee, 2005). However, due to a lack of research about IS project complexity, there is still a lack of understanding about the specific organizational and technological aspects that the authors refer to and the role of change in that context. Moreover, to the best of our knowledge there is not a single conceptual study that has examined complexity of IS projects *and* programmes, thus also differentiating between the two, despite the known differences between an IS project and an IS programme (e.g., programmes being more strategic in nature and therefore subject to stronger external influences). This provides a strong motivation for this paper, which reviews the existing literature about IS project and programme complexity to lay the foundations for future empirical research in this area, which is urgently needed.

This paper focuses on examining IS project and programme complexity through a systematic literature review of existing IS research about the topic with the goal to answer the following research question: What is the nature of complexity in IS projects and programmes? Thereby, we differentiate between IS projects and programmes, arguing that there are both similarities and differences to be considered in future empirical research. In the remainder of this paper we first discuss what is known about the similarities and differences between IS projects and programmes. Thereafter, we discuss the concept of IS complexity as a basis for examining IS project and programme complexity. Based on these theoretical foundations, we explain our research process, including an analytical framework of IS project complexity that guided our literature review and a description of the process of literature identification and selection. Drawing from the findings of our literature review, we propose a list of components of IS complexity and discuss their relevance in the context of IS projects and programmes.

2 Theoretical Background

2.1 Differentiating IS Projects from IS Programmes

IS are understood as consisting of hardware, software, data, people, and procedures which are used for collecting, processing, storing and transmitting information in order to facilitate business operations

(Schryen 2010 and Silver et al. 1995). Nowadays, organizations are becoming more dependent on IS and they play an increasingly strategic role. As a result, the implementation of organizational IS frequently involves the execution and coordination of multiple IS projects that are interrelated and all contribute to a shared goal (Denyer and Kutsch, 2011). We searched the IS literature for differences between IS projects and programmes, but did not find any systematic comparison. Thus, we also draw upon the general project management literature in the following to create a summary of differences that is the basis for the subsequent literature review of complexity in these two contexts.

A project is defined as a set of related activities which together deliver an output to the organization based on a certain time schedule and financial budget (Ribbers and Schoo, 2002). Thus, a project usually has one set of goals. When multiple projects are executed in parallel and combination, the need arises to coordinate the variety of involved sub-goals and interests, to use resources effectively, and to develop new capabilities to achieve multiple sets of interrelated goals that, taken together, are more strategic in nature. This need is addressed through a temporary organizational form referred to as programme (Pellegrinelli, 2011). A programme is considered to be "a group of projects that are managed in a coordinated way to gain benefits that would not be possible were the projects to be managed independently" (Ferns 1991, p. 149). Programmes are selected as an adequate organizational form to link interconnected projects together so that they all contribute in a coordinated way to a set of common strategic organizational goals. Furthermore, a programme is an organizational form that is suitable to manage very complex IS implementations that entail a large scope and significant organizational change (Pellegrinelli 2002, and Pellegrinelli et al. 2007). Thus, another key difference is that projects are usually relatively narrow in scope change, while programmes encompass broader scope change. On a related matter, projects tend to be relatively stable and short in duration, while programmes are relatively unstable and long (Levin and Ward, 2011). Table 1 summarizes what we found in the literature.

	Projects	**Programmes**
Focus	Less strategic	More strategic
Goals	Usually one set of goals	Usually multiple sets of interrelated goals
Change	Relatively narrow scope of change	Relatively broad scope of change
Duration	Relatively stable and short	Relatively unstable and long

Table 1: Key Differences between projects and programmes (adapted from: Levin and Ward 2011 and Pellegrinelli 1997)

In summary, there are multiple important differences between projects and programmes. However, there are also similarities, which is quite natural because a programme consists of projects.

2.2 IS Complexity

The Random House Webster's College Dictionary defines the word complex as "composed of many interconnecting parts." Complexity can be characterized by two major aspects: quantitative, related to the concepts of number and scale, and qualitative, related to uncertainty and ambiguity (Gegov, 2007). Many authors consider IS as a complex adaptive system (e.g., Benbya and McKelvey 2006; Kovacs and Ueno 2004; Merali 2006). This indicates that IS correspond to a process of continuous adaptation and change, evolving together with respect to their parts, and that IS and organizations are not only reciprocally interdependent where one shapes the other, but suffer various adaptations or re-adaptations phases (Benbya and McKelvey, 2006). Typical examples of complex adaptive systems include ant colonies, immune systems, brains, markets, and organizations. Complex adaptive systems have always existed, though complexity has been significantly increasing as a result of rapid information technology (IT) advances in the past few decades (Sargut and McGrath, 2011), leading organizations to invest increasingly in IS projects and programmes in order to implement new technologies and adapt to their competitive environment. Today, IS projects and programmes require specialized personnel, efficient methodologies and competent management resources that are able to

deal with both a more turbulent business environment and a more complex technical environment (Bygstad et al, 2010). Many organizations face difficulties in coping with their increasing complexity in IS projects or programmes (Murray, 2000). In order to better comprehend this concern, it is important to understand the characteristics of projects and programmes as a basis for understanding IS project and programme complexity.

3 Methodology

In this section, an analytical framework based on the findings of Xia and Lee (2005) is presented and discussed, which serves as a basis to structure and guide our literature review. In addition, we explain our process of literature identification and selection.

3.1 Analytical framework: IS project complexity

Although the IS project complexity concept "has often been used without precise definitions and appropriate operationalizations," a few authors have attempted to conceptualize and find measures related to this phenomenon (Xia and Lee 2005, p. 47). The framework developed by Xia and Lee comprises a comprehensive list of IS project complexity components and is to the best of our knowledge the only comprehensive study about this topic. Therefore, we used this framework as a point of departure for our literature review.

Xia and Lee define IS project complexity as the "*state of consisting of many varied organizational and technological elements that are interrelated and change over time*" (Xia and Lee, 2005). Accordingly, the authors outline that IS project complexity can be comprehended and measured along two dimensions: organizational/technological and structural/dynamic. A detailed description of their developed framework is given in Figure 1.

	Structural		**Dynamic**	
Organizational	**Structural Organizational Complexity**		**Dynamic Organizational Complexity**	
	Variety	Stakeholders (users, project team, external contractors and vendors)	Uncertainty	Requirements Business Processes Organizational structure
Technological	**Structural Technological Complexity**		**Dynamic Technological Complexity**	
	Variety	IT infrastructure Data Application	Uncertainty	IT infrastructure Data Application Software development tools
	Interdependency	Technology		

Figure 1: Framework of IS project complexity based on Xia and Lee (2005)

The authors tested their framework empirically based on interviews, focus group discussions, and survey data, incorporating knowledge from 541 IS project managers in a four-phase process in order to generate and validate components to support the measurement of IS project complexity. Their study contributed with a list of 15 IS project complexity measurement components belonging to the different complexity dimensions mentioned above. Xia and Lee also used the same framework in a related study in order to analyse the effects of the IS project complexity dimensions on project performance (Xia and Lee, 2004). Their findings indicate that regarding IS project complexity, the technological dimensions of the framework are more salient and problematic to project managers. However, the organizational dimensions have stronger effects on project performance, i.e., delivery time, cost, functionality, and user satisfaction (Xia and Lee, 2004). Consequently, more research is needed to better understand all of the dimensions and components in their framework. Although Xia and Lee's

framework captures critical aspects of IS project complexity, their 15 final measurement items are partly descriptive in nature and lack theoretical conceptualization. As Xia and Lee acknowledge, the *Structural Organizational Complexity* dimension was not exhaustively analyzed, and potentially relevant organizational factors such as business processes and organizational structure were not considered (Xia and Lee, 2005). Consequentially, our study aims at examining recent advancements in the IS literature since this study was published in order to provide a state-of-the-art review.

3.2 Literature Identification Process

The analytical framework introduced above guided the first phase of our literature identification process, which was based on a systematic keyword search. Thereby, the literature review conducted by Dibbern et al. (2004) served us as a reference example in which the literature identification process was also initiated that way. We constructed the search string based on the framework's components, i.e., stakeholders' variety, IT infrastructure variety, technology interdependency, requirements' uncertainty, business processes uncertainty, etc. Subsequently, we used this search string in the following databases: EBSCOHOST, ScienceDirect, JSTOR, IEEE Xplore and Google Scholar. The search string was applied in the title, abstract, keywords and main text of articles. The search was limited to peer-reviewed scientific literature published after the work of Xia and Lee (2005) in the fields of IS and management with emphasis on complexity and project/programme management. After an initial screening of the articles that we found through the above described search process, we quickly realized that prior studies on IS project risk are related to the selected topic of IS project complexity. As suggested by Xia and Lee, "literature on project risk factors provides an important basis for addressing the dynamic, or uncertainty-based, aspects of IS development project complexity" (Xia and Lee 2004, p. 71). Therefore, the literature on IS project risk was also included into our literature identification process.

3.3 Literature Selection Process

After the above described literature identification process, we initiated the literature selection process. The first foundational research activity herein involved a careful screening of the previously identified articles, with a particular focus on the articles' titles, abstracts, introductions, and conclusions. This activity is in line with the approach suggested by Swanson and Ramiller (1993). Articles that were not related to complexity, project/programme management, or software risk factors were excluded. To make sure that we had not overlooked any important studies, we extended our selection of relevant literature through an approach suggested by Webster and Watson (2002). This approach involved a careful reviewing of the selected articles through a systematic forward and backward search. In applying the go backward technique, we reviewed articles that were cited by any one of the previously selected articles to find relevant papers published before the selected article. In applying the go forward technique, we searched for articles citing any one of the previously selected articles to find relevant papers published after the selected article. The database Web of Science was used for the forward search. The final sample consisted of 21 articles, which we coded according to the framework of Xia and Lee. The reliability of our coding was accomplished through a process in which one of the two authors coded an article and the other one controlled and refined that coding, resulting in intensive discussions over the interpretation of the literature.

4 Results of Literature Review

In the following, we present and discuss the results of our literature review, based on the application of the above summarized framework by Xia and Lee (2005). Essentially, we found support in the literature published since this study for all of the complexity components in the different dimensions of the framework. However, we also identified some new components (see Table 2 for an overview over these *newly* identified components) in the course of our literature analysis, which we classified into the existing complexity dimensions of the framework.

Construct	Components	Description	Literature review
Organizational-Structural Complexity			
Variety	Organizational structure	• Multiplicity of vertical organizational levels, lateral business domains, roles, etc.	Maylor et al. 2008
	Location	• Multiplicity of geographical locations at which work is performed	Espinosa et al. 2007; Maylor et al. 2008.
	Goal	• Multiple different, partly conflicting and weakly correlated performance goals	Ethiraj and Levinthal, 2009.
Interdependency	Business process	• Extent to which business processes cut across multiple functional areas	Bygstad et al. 2010; Karimi et al. 2007; Schaefermeyer et al. 2012.
	Task	• Extent to which tasks are mutually dependent on one another	Bailey et al. 2010; Roberts et al. 2005; Sharma and Yetton, 2007; Xu and Ramesh, 2007.
	Resource	• Extent to which projects share the same resources (e.g., technologies, human resources)	Kappelman, 2006.
Organizational-Dynamic Complexity			
Uncertainty	Resource	• Insufficiency or change in key resources (e.g., limited experience/expertise, personnel turnover)	Benaroch et al. 2006; Kappelman et al. 2006; Roberts et al. 2005; Xu and Ramesh, 2007.
	Planning	• Unrealistic or frequent changes in plans, budgets, and schedules	Benaroch et al. 2006; Kappelman et al. 2006; Xu and Ramesh, 2007.
	Goal/Scope	• Unexpected significant changes in project goals/scope	Benaroch et al. 2006; Kappelman, 2006; Wang and Ko, 2012.
Ambiguity	Requirements	• Unclear and ill-defined requirements	Benbya and McKelvey, 2006; Jiang et al. 2009; Xu and Ramesh, 2007.
	Task	• Unclear and ill-defined tasks	Benaroch et al. 2006; Roberts et al. 2005.
	Goal/Scope	• Unclear and ill-defined goals/scope	Maylor et al. 2008; McLain, 2009; Pollack, 2007.
	Role	• Unclear or ill-defined roles and responsibilities	Cicero et al. 2010; Roberts et al. 2005.
Technological-Structural Complexity			
Interdependency	Socio-technical	• Linkage, integration, and coordination needs between the social and technical elements of an information system subject to change	Bygstad et al. 2010.
Technological-Dynamic Complexity			
Ambiguity	Technology	• Lack of understanding about the involved technologies, design techniques, programming languages, etc.	Kappelman et al. 2006.

Table 2: Results of the literature review: Newly identified components

5 Discussion of Findings

5.1 Components of IS Project Complexity

Components of IS project complexity, as opposed to IS programme complexity, have been examined more intensively in past research as exemplified by Xia and Lee (2005). In our review of project management literature that has been published since this influential study, we find support for the previously identified components of IS project complexity, i.e., variety of stakeholders, requirements uncertainty, business process uncertainty, organizational structure uncertainty, technology variety, technology interdependency, and technology uncertainty. Thus, we assume that these components are of high importance in IS projects. In addition, we identified several other complexity components that are also potentially important in IS projects, even though not explicitly included in the final conceptualization and operationalization of IS project complexity of Xia and Lee (2005).

With regards to the complexity construct of *structural organizational variety*, the component of 'multiplicity of geographical locations at which work is performed,' i.e., location variety, may be of high importance in an IS project that involves a large degree of outsourcing or offshoring. For example, Espinosa et al. (2007) argue that coordination challenges emerge when the project team is distributed across multiple geographical locations, a phenomenon that can be increasingly observed in IS projects.

With regards to the complexity construct of *structural organizational interdependency*, we find evidence in the recent literature for the relevance of three distinct complexity components that are not included in Xia and Lee (2005)'s operationalization. First, business process interdependency, which refers to the extent to which business processes cut across multiple functional areas (Karimi et al. 2007), a component that is naturally more important in IS projects that go beyond IT implementation and also involve business process reengineering (Bygstad et al. 2010). Second, task interdependency, which refers to the extent to which tasks are mutually dependent on one another, and is assumed to be an important complexity component in any IS project (Sharma and Yetton, 2007). Finally, resource interdependency, which refers to the extent to which projects share the same resources (e.g., technologies, human resources) (Kappelman, 2006), and is becoming increasingly important as IS organizations make attempts to professionalize the project organization through IS project portfolio management approaches (Gareis, 2007).

With regards to the complexity construct of *dynamic organizational uncertainty*, Xia and Lee (2005) had only included requirement, business process, and organizational structure uncertainty into their conceptualization and operationalization. However, we find evidence in the literature published since then for three additional potentially important complexity components, i.e., resource, planning, and goal/scope uncertainty. Resource uncertainty refers to an insufficiency or change in key resources (Xu and Ramesh, 2007) and may be a particularly important complexity component in IS projects that involve IS offshoring (the problem of personnel turnover is well known in the IS offshoring project literature, posing great challenges to resource stability). Furthermore, the component of resource uncertainty will naturally play a very important role in IS projects involving a large degree of difficulty and novelty for the organization, requiring particular experience and expertise that may not be currently available. Planning and goal/scope uncertainty are related to the previously identified component of requirements uncertainty, but our literature review suggests that project goals/scope, project plans, and specific requirements (e.g., user's) are different things that may all be separately subject to dynamics and change, and must therefore be viewed as individual components of IS project complexity.

A newly identified complexity construct is what we refer to as *dynamic organizational ambiguity*, contributing to Xia and Lee (2005)'s framework. We find four relevant project complexity components of this construct, i.e., requirements, task, goal/scope, and role, which all deal with a lack of clarity in specification and the associated problem of being ill-defined. It is important to acknowledge that the problem of ambiguity is different from uncertainty. The latter has been defined

in the context of IS projects as the extent to which elements in a project are "subject to future changes" (Xia and Lee 2005, p. 52), while the former has been described in the literature as meaning "confusion, lack of understanding, and disagreement" (Mckeen et al. 1994, p. 433) and therefore requires further definition and change. Thiry (2002) also emphasizes the differences between the constructs of uncertainty and ambiguity.

In the technological dimensions of Xia and Lee (2005)'s framework we identified two additional complexity components, i.e., socio-technical interdependency (part of technological-structural complexity) and technology ambiguity (part of technological-dynamic complexity). The former refers to the linkage, integration, and coordination needs between the social and technical elements of an information system subject to change (Bygstad et al. 2010) and the latter refers to the lack of understanding about the involved technologies, design techniques, programming languages, etc. (Kappelman et al. 2006).

In summary, for future research we offer a considerable extension of Xia and Lee (2005)'s framework of IS project complexity, grounded in the four basic constructs of complexity, i.e., variety, interdependency, uncertainty, and ambiguity. We summarize these overarching findings in the following Figure 2.

	Structural	Dynamic
Organizational	• VARIETY • INTERDEPENDENCY	• UNCERTAINTY • AMBIGUITY
Technological		

Figure 2: The four constructs of complexity in IS projects and programmes (variety, interdependency, uncertainty and ambiguity) in relation to Xia and Lee (2005)'s framework

5.2 Differences between Complexity in IS Programmes and Projects

We find that many components of complexity in IS programmes are closely related to components of complexity found in prior IS project management research. Our interpretation of this finding is that because IS programmes involve the execution of multiple projects, components of IS project complexity also play a role in IS programmes. However, we also argued earlier (section 2.1) that IS programmes are different from IS projects in several ways. We discuss the differences between complexity in IS programmes and projects in the following, based upon our comparison of findings with the existing literature on the similarities and differences between IS projects and IS programmes (Table 1).

First, we find that in general, there is an increased relative importance of organizational complexity components in relation to technological complexity components in an IS programme. Our interpretation of this finding is that IS programmes are typically more strategic in nature than IS projects (see Table 1), resulting for example in an even greater variety of stakeholders with different interests, expectations, etc. to be coordinated and managed.

Second, our literature review suggests that goal variety plays a larger role in IS programmes than in IS projects. As summarized previously in Table 1, a programme typically involves a plurality of different sets of goals and objectives, while a project is frequently focused on a limited goal set.

Third, the complexity component resource interdependencies plays a relatively more important role in IS programmes than in IS projects. Our interpretation for this finding is that as IS programmes involve multiple interrelated projects (Table 1), they are more likely to share resources. Furthermore, an alteration in the resources of one project may directly compromise the completion of other projects that are dependent on the same resources.

Fourth, another result of our literature review is that the identified dynamic complexity components related to uncertainty and ambiguity are of even greater importance in IS programmes than in IS projects. This can be explained, again based on Table 1, by the view that IS programmes are typically of longer duration and involve a broader scope of change than IS projects. For example, Ribbers and Shoo (2002) analysed 15 cases of IS programme implementation and found that in one of them 60 percent of the company's 419 systems had to be replaced and interfaces had to be written for the remaining 40 percent. Moreover, the account plan presented 50.000 entries which had to be reduced to 4.000. The programme implementation resulted in a new architecture of client/server software, hardware and operating system. Thus, IS programmes are potentially even more subject to dynamics than traditional IS projects.

5.3 Suggestions for Future Research

Our systematic review of literature about IS project and programme complexity suggests several avenues for future research. First of all, an important insight from our review is that IS programmes differ from IS projects in multiple ways and therefore, we suggest for future research about IS project and programme complexity to differentiate between the two. The literature provides several indications about the specific complexity components according to which IS project and programme complexity differ from one another (as discussed in the previous section), but further research is needed to examine these differences in greater detail. Furthermore, there is clearly a need for more empirical research about complexity in both IS projects and programmes. Xia and Lee (2005) have made important advancements towards our understanding about IS project complexity, but empirical research since then has been very limited. Many of the studies included in our literature review are conceptual in nature or, if empirical, only include the phenomenon of complexity in the background of their study. However, the phenomenon of complexity in IS projects and programmes is increasing, rather than decreasing, in importance, given the trends of higher levels of uncertainty, etc. in today's business. Therefore, there is a need for more empirical project management research that focuses explicitly on the phenomenon of complexity. A viable starting point would be to operationalize and empirically test our proposed conceptualization of complexity along the four constructs of variety, interdependency, uncertainty, and ambiguity (see Figure 2). A further interesting topic for further inquiry would be to examine the relationships between the different complexity components identified in our literature review. Thereby, basing the examination of these relationships upon real-world cases and expert's experiences is recommendable, while for example the performance impacts of the identified complexity components are best examined through large-scale empirical studies.

6 Conclusion

In this paper, using Xia and Lee (2005)'s framework as a point of departure, we provided a state-of-the-art review of complexity in IS projects and programmes. An important finding is that there are also differences, besides the obvious similarities, between IS projects and programmes with regards to various IS project and programme complexity components. With our analysis and discussion of these differences, we contribute to the study of Xia and Lee (2005), which did not differentiate between IS projects and programmes in their examination of complexity. Another important contribution that we make is providing a more extensive list of IS project and programme complexity components as a basis for future empirical research. Finally, we also contribute to the study of Xia and Lee (2005) by conceptualizing and aggregating the various complexity components into four constructs of complexity, i.e., variety, interdependency, uncertainty, and ambiguity. Our basic conceptual distinction into these four constructs complements Xia and Lee (2005)'s idea to distinguish between structural and dynamic as well as organizational and technological components. Thus, our extended framework offers a more comprehensive understanding of complexity in IS projects and programmes.

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